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THE VEGETATION OF THE BAY OF FUNDY SALT AND DIKED MARSHES: AN ECOLOGICAL STUDY.

CONTRIBUTIONS TO THE ECOLOGICAL PLANT-GEOGRAPHY OF THE PROVINCE OF NEW BRUNSWICK, NO. 3.[1]

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(WITH SIXTEEN FIGURES AND MAPS)

AT the head of the Bay of Fundy, in the Provinces of New Brunswick and Nova Scotia, occur extensive and diversified salt marshes. In places they merge into fresh-water bogs; elsewhere, and for most of their area, they are reclaimed from the sea and in a high state of cultivation, or are in process of reclamation; and some parts remain still in their natural state. Corresponding with these marked differences of conditions are striking differences in the vegetation; and the constant operations of diking, flooding, etc., allow all gradations of conditions, and hence of vegetation, to be seen. There is here offered, therefore, an unusually favorable opportunity to investigate some phases of the dynamical relations of plants to their environment, particularly the effects of soil and water upon their forms and sizes, upon the determination of the kinds that occur in such places, and upon the succession of one kind by another. In the present paper are contained the results of the observations I have

[1] No. 1. Upon raised peat-bogs in the Province of New Brunswick. Trans. Roy. Soc. Canada II. 3[4]: 131–163. 1897.

No. 2. A preliminary synopsis of the grouping of the vegetation (phytogeography) of the Province of New Brunswick. Bull. Nat. Hist. Soc. New Bruns. 5:47–60. 1903.

The present paper was presented in abstract before the Society for Plant Morphology and Physiology at the Yale meeting, December 28, 1899.

been able to make upon these subjects during some eight weeks of field work in the summers of 1898, 1899, and 1901, together with such a summary of the origin and development of the marshes as seems necessary to an understanding of the present subject.

Literature and other sources of information.

From the present, or indeed, from any, point of view, there is practically no scientific literature upon the vegetation of these marshes. A very brief list, of but six species, of the plants characteristic of the wild salt marsh was given by Goodwin in 1893, and references to a species or two occur in some of the papers later to be cited; but further there is nothing. Upon the geological origin, structure and economics of the marshes, however, there are valuable publications to be mentioned later. As to the literature of salt marshes in other parts of America, this also is scanty. Shaler, in two or three of his works, has given brief descriptions of the mode of formation and economics of those of the Atlantic coast of the United States, and, recently, valuable contributions have appeared by Kearney, by Harshberger, and by Lloyd and Tracy. There are references to salt marshes in Warming's and in Schimper's well-known general works, and there are papers on the salt marshes of Europe by Warming, by Flahault and Combres, and by others, and there is a synopsis of those of Germany in Drude's work.

Any account of the changes in vegetation brought about in the process of reclamation of the sea-bottoms in the Netherlands would be of interest in this connection, but such I have not found, nor have I been able to see a paper by Theen on the diked marshes of Schleswig-Holstein, mentioned by Drude (p. 390). Upon bogs, into which the marshes often merge, there is of course an ample literature, partly summarized in the first paper of this series. All of the works above-mentioned will be referred to their proper places later, and are cited in full in the bibliography at the end of this paper.[2]

[2] In the marsh country there are residents who are experts in all matters pertaining to the economics of the marshes, and from several of them I have obtained most valuable information, which I wish here gratefully to acknowledge. I am particularly indebted in this way to Mr. W. C. Milner, of Sackville, President of the Misse-

The distribution and extent of the marshes.

The marshes now under discussion possess, as will later be shown, peculiarities which clearly differentiate them from the ordinary salt marshes so common everywhere about the mouths of tidal rivers in this country and in Europe, and hence are of a type rare if not unique. The ordinary marshes are also abundant in this region (though of small extent), particularly along the Gulf of St. Lawrence shore. Others, more like those we are considering, occur in the Bay of Fundy at Annapolis Basin, at Musquash, at Pisarinco, at St. John, at St. Martins, at Martins Head and elsewhere, sometimes diked and sometimes not. But in their complete and perfect form, the Fundy salt marshes are confined to the two heads of the Bay, *i. e.*, to Minas Basin and Chignecto Bay; and they are largest and finest in the latter. Their extent and distribution are very clearly shown upon the surface geology maps of this region, and, for Chignecto Bay, in the accompanying map (*fig. 1*). In Chignecto Bay they begin at Rougie (or Petit Rocher), just west of Cape Enrage, and thence extend irrregularly to the Shepody River; they occur in places along the Petitcodiac and Memramcook Rivers, and reach their perfection of size, economic value and scientific interest at the head of Cumberland Basin, whence they radiate up the valleys of the several small rivers of that district, the Tantramar, Aulac, Misseguash, LaPlanche, and (to a lesser extent) the Nappan, Maccan and Hebert. Largest of all is the combined Tantramar-Aulac marsh, shown in detail upon the accompanying map (*fig. 2*), and it is this, with the Misseguash marsh and the Shepody marsh, that I have studied.

The total area of the marshes with the related bogs is only approximately known. In 1895, Mr. Chalmers, of the Geological Survey, after a careful computation, estimated 34,300 acres of diked and undiked marsh in New Brunswick, of which 9,100 acres were in Albert county west of the Petitcodiac, and 25,200 in Westmorland north of the Misseguash. Mr. Monro, a profes-

guash Marsh Co.; to Mr. Howard Trueman, of Point de Bute; and to Mr. William Fawcett, of Upper Sackville. Mr. F. A. Dixon, of Sackville, has aided greatly by collecting for me seeds of many of the marsh plants.

sional surveyor who was engaged upon all of the principal surveys of these marshes, estimated in 1883 that the diked marsh (the undiked is comparatively insignificant in quantity) on the Nova Scotia side of the boundary contained 12,600 acres, while New Brunswick had on the Tantramar, Aulac and Misseguash,

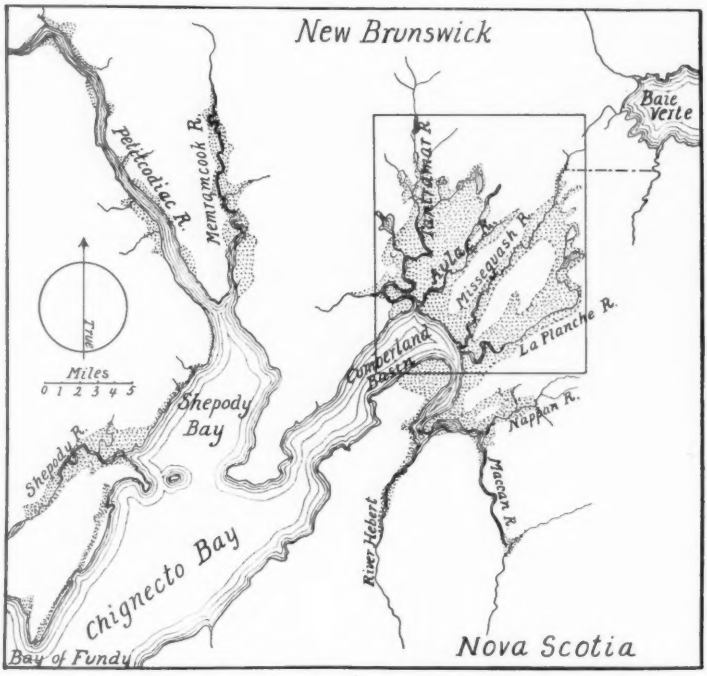

FIG. 1.—Sketch map of the marsh country, showing (dotted) the distribution of the principal marshes. The area enclosed by the quadrangle is shown enlarged in *fig. 2*.

19,400 acres. Of still unreclaimed bog lands (everywhere underlaid by marsh), there were on the LaPlanche 1,000 acres, on the Misseguash 3,700 acres, and on the Aulac and Tantramar 4,000 acres. Thus there are about 40,700 acres of marsh and bog about Cumberland Basin, of which 25,000 acres belong to New Brunswick, and 15,700 acres to Nova Scotia. Their approximate extent in this vicinity, and the relative amounts of wild

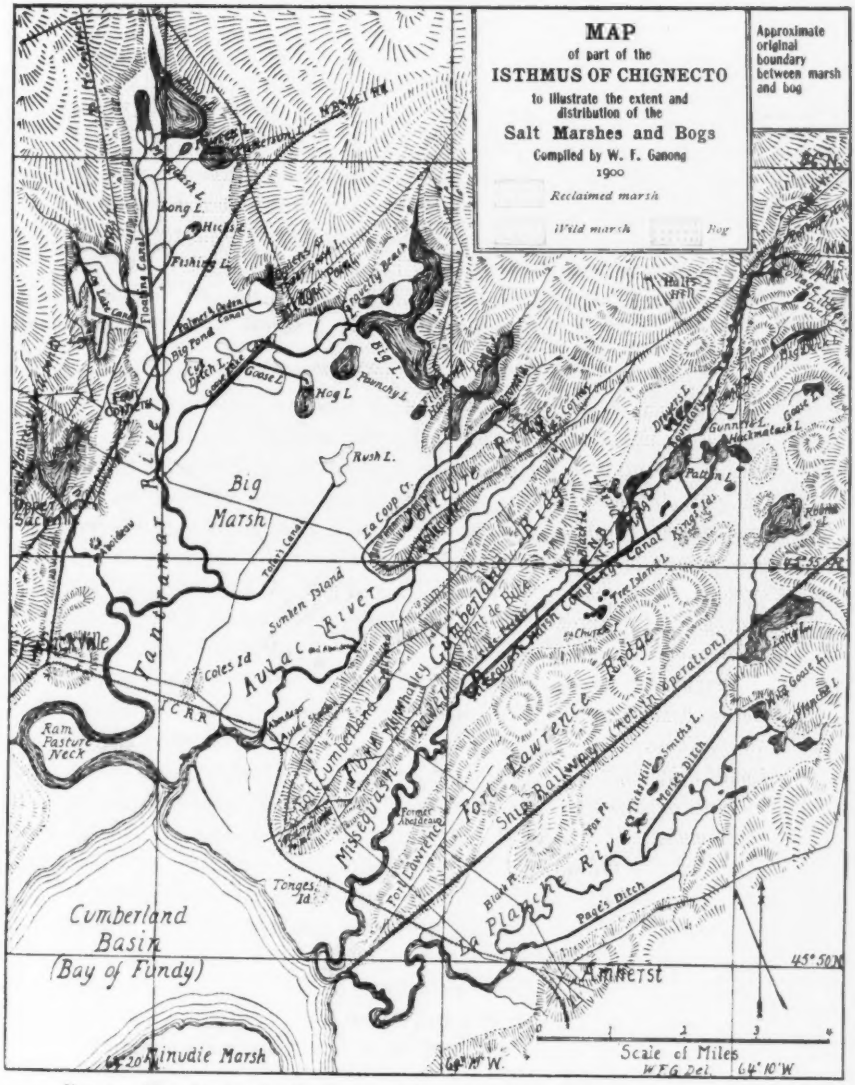

FIG. 2. — Map showing the distribution of the principal salt and diked marshes and bogs.

and reclaimed marsh and bog, together with the outlines of these marshes, may be gathered from the accompanying map (*fig. 2*) drawn to the scale of two miles to an inch. The marshes on Minas Basin are much less in area than those on Cumberland Basin, but in the aggregate there are at the head of the Bay of Fundy not far from 70,000 (or as Hamilton estimates, 80,000) acres of marshes and bogs, of which by far the greater part is diked and under cultivation. The extent of the diked marshes may be yet better understood when it is stated that, according to Shaler, the entire area of all of the diked salt marshes of the eastern United States does not exceed 5,000 acres.

The characteristics of the marsh country.

The country around Cumberland Basin is of ancient (Palaeozoic) formations, rounded into low smooth hills and ridges separated by radiating river valleys. Among the ridges lie the marshes, seemingly level as the sea; and, like it, they fill bays, surround islands and are pierced by points. Seen from the neighboring ridges, the marshes have an aspect characteristic and beautiful. They are treeless, but are clothed nearly everywhere with dense rich grasses in many shades of green and brown, varying with the season, with the light, and even with the winds. For the most part the merging of the colors is irregular; but in places, owing to the different treatment given by different owners to their land, or to the presence of fields of grain or pasture-lots, there is something of the checkered appearance usual in highly cultivated land. The frequent ditches marked by denser growths, the rare fences and the occasional roads or railways are other signs of the operations of man. Towards the sea are narrow fringes of unreclaimed marsh, poorer in vegetation and generally duller in color, while farther back the green of the marshes gives place to the brown and gray of the bogs, which are further distinguished by irregular shrubbery and trees, and many little lakes. Nobody lives upon the marshes, but scattered upon them are many great barns, all of one and the simplest pattern, unpainted and gray from the weather, standing at any and every angle. These barns are one of the distinguishing features of the marshes, and give to

them a suggestion of plenty which is a true index of the economic condition of this region, for here are the most prosperous and progressive farmers, and the most thriving country towns in eastern Canada. Especially characteristic of the marshes are the tidal rivers which have helped to build them. As is well known, the sea here shows a great range of tides, even to over forty feet.[3] The tidal rivers, winding in the most sinuous courses through the marshes, at times run full to their bordering dikes, loaded with brownish-red mud; but the fall of the great tides sends their thick currents tumultuously out, to leave but tiny rills between deep gaping gashes of slippery mud gleaming in the sunlight. Thus too are extensive flats laid bare about Cumberland Basin. The suspended mud gives both to the rivers and to the sea a dull-red color which is a striking and a characteristic feature of the scenery of the marsh country. Not all of the rivers, however, are red, for from some of them the sea has been shut out by ingenious dams, and in each of these the banks are clad with dense green grass to near the bottom of the bed, along which winds a small fresh-water stream.

When one goes upon the marshes from the upland, he is likely to think them misnamed; for instead of the soft bottom and the rank growth associated with the word marsh, he finds everywhere a soil as firm as the upland itself, and, on the reclaimed parts, a growth of the finest grasses, luxuriant but not coarse. Indeed, a near view of the reclaimed marsh shows scarcely anything different from the best of fine-soiled upland grass land.

The marsh country is beautiful to look upon, and in addition there hovers over it the charm of a long and varied history. It was a part of the ancient Acadia and inherits the memories of

[3] The height of the tides in this region is popularly exaggerated. Careful measurements have given for Cumberland Basin a range of 38 feet for neap and of 45.5 feet for spring tides. Exceptional tides have had greater range, and the greatest on record (the Saxby tide of 1869) had a range of about 70 feet. The tides at the head of Minas Basin are ordinarily somewhat higher than in Cumberland Basin. Fuller particulars may be found in the Admiralty charts, in a "Report . . . . on the construction of a canal between the Gulf of St. Lawrence and the Bay of Fundy," Ottawa, 1874, and in a Report on a "Survey of tides and currents in Canadian waters," by W. Bell Dawson, Ottawa, 1899.

that picturesque but ill-fated country. The student in his wanderings meets with many a reminder of the ancient régime.

The geological origin of the marshes.

An understanding of the origin and formation of the marshes is so important to the interpretation of some of the peculiarities of their vegetation, that a somewhat full account of it is needful here.

The subject was first touched upon by Lyell (in his *Travels in North America*, 1845), but received its first systematic discussion from Dawson (in his *Acadian Geology*, 1855, repeated in later editions). Subsequent accounts, with some additional facts, are given by Monro (1883), by Chalmers (1895), by Trueman (1899), and in more popular fashion by Dixon (1899); while an extremely good synopsis of the whole subject has been contributed by Eaton (1893). From the point of view of the tidal action in their formation there are papers by Hamilton (1867), by Matthew (1880), and by Murphy (1886), and of course scattered references by others.

The central fact in the formation of the marshes is this: they have been, and still are being, built in a subsiding basin out of inorganic red mud brought in from the sea by the rush of the tides, whose height is the determining factor in their height. Practically no part of their mass has been built from detritus brought down by rivers, which in this region are altogether insignificant in volume; nor has vegetation, either marine or land, helped to any appreciable extent to build them. I believe no observer of the mode of their formation could doubt that they would be as high and wide as they are today had never a plant grown about or upon them. It is these two facts, their formation out of a purely inorganic mud brought in by the sea, and the lack of cooperation of plants in their building, which differentiate them from the salt marshes so common elsewhere about the mouths of tidal rivers.

Whence, then, comes this great store of rich mud? On this all students agree; it is from the red Permo-Carboniferous sandstones forming the sides and bottoms of the channels between the marshes and the Bay of Fundy. These soft rocks are

rapidly eroded by the strong tidal currents, which, in their onward rush to the northeast, carry the detritus whirling in suspension, to drop it as their force is checked by their quiet spread over the marshes at the highest tides. Thus, the sea bottom supplies the materials, the rush of the tidal currents the power to remove, carry and lift them, and the quiet of the waters at the turn of the tide the condition allowing them to be dropped. In this way the sea is building up the land, perhaps on a greater scale here than elsewhere on the globe.[4]

The quantity of mud needed to form the marshes has been immensely great. Not only do they cover many square miles, but borings show that they can be as deep as eighty feet at least ;[5] and moreover, the marsh mud extends also everywhere under the bogs and shallow lakes clear to their utmost bounds. To supply this quantity, the channel to the bay (Chignecto Channel) must have been enormously widened and deepened, and hence it must have been very small when the process began. The sea has quarried out the channels, and the marshes are the debris. This process has been aided, or, perhaps more properly, has been allowed, by the recent subsidence of this region, of which the indisputable evidence is found in the buried forests well known to exist at several points under the marsh much below high-tide level. Dawson first described the stumps of a beech and pine forest, the wood still sound, rooted on Fort Lawrence Ridge, thirty to thirty-five feet below high-tide level. Chalmers and others have described other cases, particularly stumps laid bare, over thirty feet under the surface, in the ship-railway dock,[6] and I

[4] The power of these tidal currents in eroding the underlying rocks has been well set forth by Matthew, in his "Tidal erosion in the Bay of Fundy."

[5] Chalmers, Geological Report 1885, M, 129 : according to the same investigator however (*op. cit.* 41) this depth appears to be so great in consequence of a fault at this place. He apparently means that the downthrow took place while the mud was accumulating. The depth of 150 feet assigned to the mud at this place by Trueman, is based, as he informs me, upon the recollection of a resident as to the depth of the boring described by Mr. Chalmers. The official figures of the latter, however, make the depth somewhat under 80 feet.

[6] The ship-railway, a great work designed to transport vessels across the Isthmus of Chignecto by rail in lieu of a canal. Though over three-fourths finished, work upon it has been suspended and is unlikely to be resumed.

have myself seen such stumps in position. The soundness of the wood shows how recent the subsidence must have been. Another fact important in this connection is the presence of a bed of peat twenty feet thick under eighty feet of marsh mud, as shown by a boring at Aulac described by Mr. Chalmers. The same observer has also found that in other places the marsh mud is underlaid by post-glacial clay containing shells of species still living in this region, though in clearer and quieter waters than now prevail in Cumberland Basin, and that this clay merges without break into the marsh mud. Grouping together these facts, the history of the marshes would appear to have been as follows. At a comparatively late post-glacial period, the land must have stood much above its present level.[7] At that time the present Cumberland Basin was a shallow lake around which peat bogs were growing; it received the waters of the seven small rivers still flowing into it, and emptied by a single narrow fresh-water channel along the course of the present Cumberland and Chignecto Channels.[8] The subsidence of the land (the same which has drowned the lower valleys of the St. John, St. Croix and other rivers of this region), allowed the tide to creep farther and farther up this channel until it reached the lake above, which it converted into a brackish, and later a salt, lagoon. At first the water would not be very muddy nor the tidal fluctuations great in the lagoon; but as the land continued to sink, the currents would become more powerful, erosion more active, and the water so muddy that marsh formation would begin around the margin of the basin and at the head of tide on the rivers. Thus, gradually, the conditions of the present day were brought about.[9]

[7] Not necessarily over 80 feet, the greatest known depth of the marsh mud, and even much less if Chalmers (Report, 41) is correct in ascribing a part of this depth to post-glacial faulting.

[8] The depth of the channel to the sea is consistent with this view. The best Admiralty chart (No. 354, "River Petitcodiac and Cumberland Basin") gives the least depth over a rock bottom as 5½ fathoms at extreme low tide, or about 80 feet below high tide. A deeper channel may however exist in the mud or sand on either side of the rock bottom.

[9] An important question arises as to whether this subsidence is still in progress. The evidence is conflicting, and the various students of the subject are not agreed. I believe it is still in progress for these reasons: first, it is still going on in other parts of

The mode of formation of the marshes.

So much for the origin of the marshes as a whole; we consider next the actual process of marsh-building by the sea. It may best be observed along the tidal rivers, which play an indispensable part in the building of the greater marshes. At ordinary tides the rivers do not overflow their banks nor reach the dikes at all. But at the spring tides every month they rise higher, the waters rush more swiftly, and, gathering up yet more mud from banks and bed,[10] overflow the banks, and, unless stopped by the dikes, spread abroad over the marshes. When the water thus leaves the channels, however, its speed is at once checked, and soon it comes to entire rest: it can no longer carry its burden of mud, and drops most of it. The water leaves the rivers so muddy one can see scarcely an inch or two into it; it returns, a few minues later, fairly clear. The thickness of mud deposited at a single tide varies from a small fraction of an inch on the higher places, to several inches on the bottoms of lakes which have been opened by canals to the tide.

The powerful tidal currents in the crooked rivers cause constant and rapid changes in the soft muddy banks, and all the phenomena of the wandering of rivers in a flood plain may here be seen upon an unusual scale. In fact the marshes are really the flood plains of the tidal rivers, though built by materials

Acadia (as shown in Bulletin of the Natural History Society of New Brunswick 4:339); and second, everywhere outside of the longest-built dikes the marsh is built up higher, even to two feet or more, than it is inside the dikes. Since the marsh was built as high as the tides could reach before it was diked, the land must have sunk to allow it to build so much higher now, even allowing for some sinking of the marsh through the removal of its mineral matters with the crops. Further, the ease with which the tide floods old marsh when admitted, building it up a foot or more, seems explicable only in this way. A case is known on the Tantramar marsh where a large ditch diked upon both sides was neglected, when it filled itself up with mud to a height of two feet above the surrounding marsh.

[10] The percentage of mud in the water is not so great, however, as it appears and as popularly supposed. To the eye it seems often to be little more than "liquid mud." By use of a graduated measuring glass on the end of a long cord I have taken samples from the bridges at various places, which, after settling, allowed the percentage of mud to be determined exactly. I have found the greatest amount in the rivers emptying out at low water, when it rose to an extreme of 4%, and it ranged at other times and places from that downward. At flood tide I have nowhere found it reaching 2%.

carried up their course instead of down. This wandering of the rivers explains many marsh phenomena otherwise very puzzling, such as the occasional miniature cliffs in the high marsh, and the layers of peat or blue mud (both formed only in presence of fresh water away from influence of the tide), exposed by canals, or even by the river itself, which thus reaches places formerly far removed from it.[11]

When the waters spread over the marsh, they of course drop most of their mud, and particularly its coarser parts, on and near the banks, thus building the marsh higher there than elsewhere. Hence the drainage of the fresh water, falling on the marshes as rain or draining upon them from the upland, is obstructed, and it tends to accumulate in the lowest places, viz., those farthest from the rivers, and hence near the upland or in basins between rivers. This fresh water allows the development of a fresh-water vegetation which initiates the formation of true bog, a point of immense importance in the ecology and economics of the marsh-vegetation. Again, at the head of tide in the rivers, the incoming salt water meets the outgoing fresh water and drops its sediment. Thus the rivers are tending always to dam themselves up at the contact of salt and fresh water, and they would doubtless do so completely were it not for the scouring out of the channel by the fresh water when the tide is out. The heads of the rivers, too, show another important phenomenon, viz., the level of high tide is higher there than at their mouths owing to the tendency of tidal rivers to pile up their waters on account of the inertia of their rush.[12] It hence comes about that the marsh is actually higher at the head of a river than at its mouth and the highest part of a marsh is at the

[11] It explains also the presence of concentric lines of old French dikes at Prospect Farm on the Aulac, and probably elsewhere, and the fact that the Misseguash is not now in the same position at Pont à Buot which it has on the very detailed maps of Franquet in 1754. It leads also to the occasional abandonment of pieces of marsh too small to be kept diked profitably.

[12] Mentioned in all works on tidal rivers. I have been told, as a good example of it, that the railroad levels show the high-tide level of the Petitcodiac to be higher at Salisbury than at Moncton; and Dixon and Trueman mention that at the big oxbows on the Tantramar, at very high and rising tides the water pours back over the neck into the river again.

head of the tidal parts of its rivers. This is finely shown by the levels taken on the Misseguash by the engineers of the Marsh Company, of which a condensed compilation is given herewith (*fig. 3*). Where the heads of the rivers wander, as they are particularly liable to do on account of the struggle between the fresh water and the dam at head of tide, a large part of the marsh may be thus elevated at tide-head, and in consequence the drainage above it is greatly obstructed. This results in a great accumulation of fresh water, with a consequent formation of immense bogs; and thus have originated the great bogs at the heads of the Tantramar, Aulac, Misseguash, and LaPlanche.

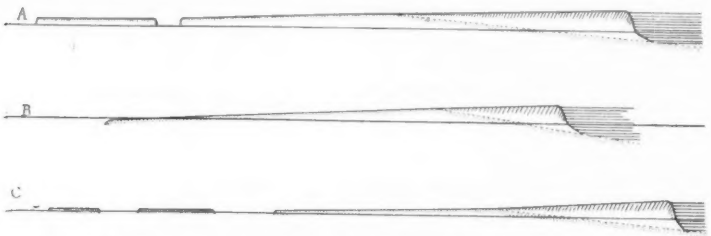

FIG. 3. — True levels on marshes and bogs determined by spirit-level; condensed from the plans of the Misseguash Marsh Co. Marsh is dotted and bog is shaded. The horizontal line is average high water in Cumberland Basin. Breaks in the marsh are where the levels ran along the river. Vertical scale 40 feet = 1 inch; horizontal ½ inch = one mile. *A*, from the Misseguash River near the railroad to Round Lake (*fig. 2*). *B*, from the La Planche River near the railroad to Long Lake; *C*, from Cumberland Basin to Long Lake.

Bogs therefore exist along the margin of upland, between rivers in the same basin,[13] and at the heads of rivers. Their extent, and their position relative to the cultivated and salt marsh may be learned from the accompanying map (*fig. 2*). In a general way the head of tide on the rivers, that is, the highest part of the marsh, marks the transition from marsh to bog; above this point, the rivers are fresh-water streams meandering through bog and expanding here and there into lakes.

The merging of the marsh into bogs is of course very gradual, and it is a well-known fact that the marsh mud extends every-

[13] Of which a perfect example occurs in the "Sunken Island" between the Tantramar and the Aulac (*fig. 2*).

where beneath the bog, even beneath the great bogs at the head of the tidal rivers. Soundings through the bog are easily made, and they show that the depth of the surface of the marsh mud from the top of the bog increases from nothing at the head of tide down to 6 or 7 feet away from the high part. Not enough soundings are available, however, to prove whether or not the slope is gradual from the high marsh to the extreme heads of the bogs, but so far as they go the soundings show this to be in general the case. This is confirmed by the water levels in the canal of the Misseguash Marsh Company. Where the canal

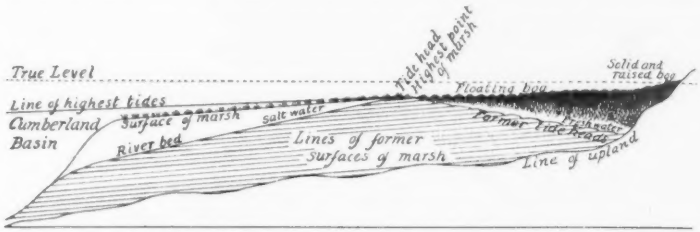

FIG. 4. — Ideal longitudinal section the marshes from sea to upland, to illustrate their origin.

passes through the highest part of the marsh near Black Island, the surface of the mud in July was nearly three feet above the water level; two miles up the bog, however, with a very slight current in the canal, the surface of the mud had dipped under the water, and the slope between the two points was perfectly gradual. It is fair to conclude therefore that the surface of the mud slopes away continuously from tide-head to the extreme distal margin of the bog. The question now arises, why this slope, which carries the bottom of the bog much below high-water level? No doubt the answer is to be found in the subsidence of the land already spoken of. Each part of the under-bog mud must at one time have been the tide-head and the highest part of the marsh; the newer tide-heads would be nearest the present one, and they would be progressively older, and hence have been carried deeper by the subsidence, the farther they are from the present one. This condition is diagrammatically represented in *fig. 4*.

The origin of the great bogs is thus made plain, but why are they mostly of the floating type? They are in fact almost entirely of this kind, though in places they are solid, and even approximate to the raised or *Hochmoor* type. They quake when one walks upon them, and a stick thrust through them penetrates from one to four feet of moss, then goes through a foot or two of water and soft organic mud before reaching the solid marsh mud. The foot or two of water seems to be fairly constant everywhere except in the shallowest parts, while the thickness of the mat of floating moss increases from the shallower towards the deeper parts, as illustrated diagrammatically in *fig. 4*. The levels (*fig. 3*) also show that the surface rises as the bog grows thicker, as is to be expected. It is a general rule in bog-formation over large basins that the floating bog is the first stage, and this is followed, as a result of growth and compacting, by solid bog, which in turn is succeeded by the raised or *Hochmoor* type. It may be a fact, therefore, that the floating character of these bogs is due to their youth — they have not yet had time to form the solid and raised types except on their oldest parts, around the margins and at the heads of the bog rivers, where such types do in fact occur. On this explanation one at first thought attributes the numerous lakes to places which the bog has not yet overgrown. But this explanation is in several respects not satisfactory. The facts seem to show that the growth of bog has been continuous from the upland outward to the marsh. Moreover, the lakes are always deeper than the surrounding bog. It seems, therefore, that there must be some positive factor tending to keep them open.[14]

[14] Possibly it may be connected with the presence in those places of a sufficient supply of salt to prevent the formation of the strongly salt-shy (halophobous) bog vegetation. As the efflorescence of salt on the mud thrown up from deep in the bog by the dredge of the Misseguash Company shows, some salt still exists in the mud beneath the bog water. This must be slowly dissolved out by the bog water, and the solution would settle towards the deepest places, which are the lakes, and might accumulate there to an extent sufficient, when stirred up by the waves, to keep them open of vegetation. The meaning of the deeper places over which the lakes lie is not so plain, but probably they represent in part portions of old river channels. This possible presence of some salt in the bottom water of the bog cannot, of course, explain the floating character of the bog, since the lower layers of vegetation are dead and unaffected by it.

A physiographic fact of some interest about the lakes may here be mentioned.

Economics of the marshes.

I. *Crops and prices.*—When reclaimed from the sea the marshes are wonderfully fertile, and in this respect they are unsurpassed, if they are equaled, by any land in eastern Canada. They are not, however, equally good for all crops, but are best for grasses and grains, to which consequently they are almost entirely given up; root crops will grow upon them, but not to advantage. They form also extremely rich pasturage, and to some extent are used for this purpose. The grasses which grow upon the best parts are the usual upland English hay grasses, which become very tall, very dense, and of very superior quality, luxuriant but not rank, producing easily three tons and upwards of the best hay to the acre. In less well drained places, coarser grasses grow, but these too are of good value. No attempt is made to take two crops a year, though some farmers allow their cattle to fatten on the rich aftermath. No fertilizers of any sort are placed upon the marshes, and the only cultivation consists in an occasional plowing, on an average once in ten to fifteen years, when a single crop of oats is sown, after which the land is brought at once into grass again.

The fertility of the marshes depends upon two, perhaps upon three, features. First there is the presence of the substances and conditions necessary for the perfect nourishment of the crop, as shown by its luxuriance. Second, the fertility is extremely lasting. The best marsh may be cropped with unlimited yield for decades together without any return to the soil. There are places on the Aulac, which are known absolutely not to have been renovated in any way since 1827, and are believed not to have been treated in any way for fifty and perhaps a hundred and fifty years before that, which are bearing today crops as bountiful as ever. There is on this river, at Prospect farm, a small triangle, known not to have been even plowed for over forty years, which has never ceased to bear a luxuriant crop of the best English hay grasses. These are of course among the

Some of them are in contact, particularly on their northeastern margins with the uplands and have there gravelly beaches. This is no doubt correlated with the prevalence of strong southwest winds in the region, which cause a surf on the northeast shores unfavorable to the development of bog vegetation.

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best places; but there are parts, particularly on the marsh longest reclaimed, which show more or less exhaustion.[15] Such marsh may have its fertility largely restored by fresh mud brought in by the sea when allowed behind the dikes. Third, the water conditions of the marsh soil are such that the vegetation is somewhat less affected by dry seasons than is that of the uplands, and a bad hay year for the uplands is not so bad for the marshes. The causes of all these peculiarities in the marsh fertility will be discussed later.

The result of this combination of good qualities is, naturally, to give the marshes a high value. Marsh situated near the towns, and well-placed for drainage, is worth upwards of $180.00 to $200.00 per acre; there are large areas valued at $100.00 an acre, while prices range, of course, from these downwards.

II. *Mode of reclaiming the marshes.*—The original marsh as built by the sea bears a sparse vegetation of typical salt marsh plants, of which only a few of the grasses, and these to a limited extent, are useful. To reclaim this marsh three things are needed: (1) to shut out the sea, (2) to wash out most of the salt, (3) to provide for the removal of the fresh water falling as rain or draining from the upland. The sea is shut out by dikes of the usual sort. These are triangular in section, built of the marsh mud itself, often with a core of stakes and brush. Against the open sea they may be six feet high, and they are protected from the wash of the waves by lines of stakes or piling and loose stones; but along the rivers they are much lower, for up the rivers the marsh itself is progressively higher. The removal of the salt takes place naturally by action of the falling rain, which washes it through the drains into the sea. It requires three to four years in newly reclaimed marsh to do this sufficiently to allow the more useful grasses to grow, and during this time there is an entirely natural succession of plants accompanying the freshening, whose kinds and sequences will presently be discussed. To allow the rain-water to drain off is all-important, not only for removal of the salt and for proper aeration of

[15] This is not to be confused with degeneration through bog-formation on account of defective drainage, a common but morphologically very different phenomenon.

the soil, but also to prevent the ever-present tendency to formation of bog plants. This drainage is accomplished by a system of open ditches, which, small and only a foot or two deep away from the rivers, are much larger and deeper near them, partly to give a fall and partly because of the greater height of the marsh there. At the outlets of these ditches on the rivers the fresh water is allowed to drain out by an arrangement that does not allow the tide to enter, namely, by placing under the dike a wooden "sluice" in which hangs a "clapper," hinged at the top and inclining outwards toward the river at the bottom (*fig.* 5). When the tide is out, the pressure of the fresh water

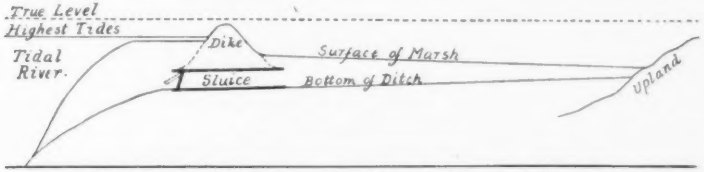


FIG. 5. — Diagrammatic cross-section through the marsh from tidal river to upland, showing a sluice.

opens this; when the tide rises its weight tightly closes it. Of course the fresh water then accumulates in the ditches, but never for long, for the sluice is not far below high-water mark. These sluices and clappers last indefinitely, apparently preserved by some antiseptic action of the salt water. A sluice of this kind is used not only in the ditches but frequently in a dike thrown across an entire river, as in the case of the Aulac. The entire structure, dike and sluice, is then called an "aboideau," and such a river is said to be "aboideaued."[16]

[16] A word introduced by the Acadians from Saintonge, France, where it is still used in the form *aboteau*. Its origin is fully discussed in the New Brunswick Magazine **1**: 225, 226, 284, 340, and **3**: 218. Naturally some other peculiar uses of words have grown up in the marsh country. Thus, the word tide is used for the salt water itself, and one often hears "let the tide on the marsh." Also the word is used constantly as a verb, as "They intend to tide the marsh," *i. e.*, to let the salt water on it, and "It was tided last year." The word ditch is used also as a verb. A large section of marsh surrounded by a single dike is called "a body." In Nova Scotia, the word dike is applied to the marsh itself (no doubt abbreviated from "diked land"), while the dike is called the "running dike," but the usage in New Brunswick is as in this paper. The word *marsh* itself is rather a misnomer and is said locally to do the country some damage by giving an unfavorable impression of its character.

The process of flooding a piece of land that has degenerated through cropping, or through bog growth as a consequence of neglect of drainage, is simple. The dikes are broken down at convenient places, and the tide is allowed to flow at will over the old marsh. Bog vegetation is killed immediately by the salt water, and it, as well as the entire marsh surface, is soon covered with several inches to a foot, or even more, of new mud. This requires from one to three years according to the situation of the marsh.[17] The dikes are then rebuilt, ditches are opened, the vegetation goes through its usual cycle, and in from two to four years it is again bearing rich English hay. This flooding, however, is by no means as extensively used as it should be, for many owners are unwilling, or cannot afford, to lose all return from their land for several years. Sometimes an attempt is made to flood and obtain crops simultaneously, by admitting only a little tide at a time, or by admitting it only in late autumn after the ground is frozen, when the grasses are little injured by it. But such compromises are considered not to pay in the end.

The struggle with the fresh water is incessant, and is the greatest care and expense of the marsh farmer. Poor drainage soon leads to the replacement of the valuable English hay by the less valuable sorts, which in turn yield to yet coarser kinds, the series ending in the appearance of useless sphagnum mosses and bog plants. Abundant and intelligent ditching is the only remedy. Farmers differ so much, however, in willingness or ability to face this problem, that areas alongside of one another under similar natural conditions with but a ditch between differ greatly, one bearing the richest English hay, and the other only the coarser kinds.[18]

[17] It seems remarkable that no attempt has been made to hasten this process by utilization of the powerful currents of the rivers to turn wheels which could pump the water and mud upon the land. Such wheels are used in other countries for irrigation purposes.

[18] There is, however, another difficulty, much more serious, which greatly hampers both the struggle with the bog and the renovation of old and exhausted marsh. The dikes are built and maintained at the common expense of a large number of owners of marsh land, and enclose a huge "body" of marsh. Owing to differences of location and of treatment, some parts of such a body come to need tiding while others do not, and

So much for the reclamation and renovation of the marshes. In addition there has grown up within a century a most important practice of reclaiming and converting into marsh both the lakes in the bogs and the bogs themselves. Its principle is simple, though the practice is by no means so. Canals are dug from the tidal rivers into the lakes, whereby the latter are drained and the tide is allowed to enter with the rich mud. In this way a lake may be entirely filled with mud and become the richest of marsh, and this has been done in the several lakes shown by the red lines on the detailed map (*fig. 2*). After the lakes have been thus reclaimed, the surrounding bog is attacked. The salt water turned upon the bog kills at once all vegetation, which compacts, sinks, becomes covered with marsh mud and gradually comes into rich marsh. Immense areas have thus been reclaimed on the Tantramar system, as shown upon the map above cited, and the process is steadily going on, while a systematic attempt is being made by the Misseguash Marsh Company to reclaim on a large scale the lakes and bogs on the Misseguash. In such operations the most constant care is needful to prevent the canals from damming and filling themselves up, and this is mainly accomplished by utilizing the outward rush of the fresh water to scour out the channels. The great aim, therefore, is to secure the greatest possible "rush of tide up, and of freshet down." There are marsh farmers who have become very expert in lake and bog reclamation, to their own profit and the good of the community. I believe this process of reclaiming bog, here practiced, is entirely unique.[19]

An important feature of the economics of the marshes is the aboideaued rivers, already explained, of which the Aulac is by

there are all gradations between. Disputes then arise among the owners of the body as to the course to be pursued, which often go so far that nothing at all is done, and great stretches of marsh suffer so severely as to become of little value. This is most markedly the case on parts of the Shepody marshes, large areas of which, capable of the highest development, are lying nearly ruined through the inability of the owners to co-operate for the common good. It would seem proper for the local legislature to interfere in such cases, where not only the interests of some owners are concerned, but also the prosperity of the neighboring region.

[19] The process is more fully described in the papers by Crawley, by Goodwin, and by Trueman, cited in the bibliography.

far the best example. An aboideau, shutting out the tide while allowing drainage of fresh water, recovers at one operation, without the expense of river-dikes, all the marsh along the river above it, and also the banks of the river and much of its bed, both of which, but especially the banks, produce the very richest of hay. At first sight it might seem wise to aboideau all rivers at their mouths, but when it is remembered that no land above the aboideau can be renewed by the tide, nor can any bog or lake be reclaimed, it will be seen that an aboideau is only profitable on streams which have no bog nor lake at their heads, and which have a soil so deep as not to need renewal. This is true of many smaller streams heading against upland, but of none of the rivers excepting the main Aulac. An aboideau upon the Tantramar would have prevented the reclamation of thousands of acres which are now productive. Naturally, therefore, there is much jealousy of aboideaus upon the part of those who own inferior marsh or bog above them, and the words of a local writer,[20] who calls them "the curse of our rivers," reflect a common opinion.[21]

[20] MR. WM. FAWCETT, of Upper Sackville, in newspaper articles.

[21] The marshes were first reclaimed by the Acadian French, who began the work in 1670 and continued it, raising much grain, until expelled by the English in 1755. They developed the methods of reclamation (of marsh, but not of bog) still in use, and many of their old dikes are still to be seen. The extent of their operations is well shown upon several maps of the time (particularly on "A large and particular Plan of Chignecto Bay," 1755), and its limits are marked by the fine dotted line drawn on the accompanying detailed map (*fig. 2*). The lands lay vacant from 1755 to 1760, after which they were regranted to New Englanders and English, and their settlement and reclamation has continued steadily to this day. In 1827 the Aulac was first successfully aboideaued, as were later the Misseguash and the La Planche, though from both of the latter the aboideaus have since been removed. No attempt was made to reclaim bog and lake until early in the last century, when a farmer of Upper Sackville, Toler Thompson, whose name is justly held in high honor in the vicinity, after long study of the tidal currents and bog levels became convinced that the lakes could be filled and reclaimed. It was long before others could be convinced, but finally a canal was dug from the Tantramar into Rush Lake (*fig. 2*) which quickly became rich marsh. Later Goose Lake was recovered, and later Log Lake (which required fifteen years to fill with mud), while Long Lake, Ogdens and others are now being filled, and thus the system initiated by Thompson is adding immensely to the wealth of this region. On the Misseguash little had been done, but five years ago a company "The Misseguash Marsh Company" was organized to attempt to do with ample capital, systematic methods, and favorable legislation, what had been done piecemeal

One other phase of the economics of the marshes remains to be mentioned. They are absolutely healthful. No malaria nor other disease is known about them. There is a local tradition that men have died from drinking the bog water; but I am told by a local physician that cases of typhoid fever are referred to and that these were probably contracted in quite another way.

The importance of the ecological study of the marsh vegetation.

From a systematic or floristic point of view these marshes are of slight botanical interest. They contain no species that are peculiar to them, out of range, or otherwise remarkable. The plants of the unreclaimed marshes, and also of the bogs, are those ordinarily occupying such situations in this part of America, while the fully reclaimed marsh is but a good hay meadow, bearing grasses altogether like those abounding on the cultivated uplands round about. Yet from another, namely, the ecological point of view, the marsh vegetation is replete with scientific interest, for the marked gradations of physical conditions of soil and water within a limited space, and, owing to artificial changes, within a limited time, allow us a rare chance to trace upon a large scale the effects of those important conditions upon the plants, and to draw some conclusions as to the nature of the adaptation of the one to the other. It is necessary, first of all, to study carefully these, and other, physical factors to which the plants must respond; then we may trace the responses in the plants.

The factors determining the ecological features of the marsh vegetation.

The principal ecological factors, as arranged in Schimper's comprehensive work, *Pflanzengeographie auf physiologischer Grundlage*, are the following: *Water, temperature, light, air, soil, animals*

on the Tantramar. This company is now vigorously at work, and it is hoped that their efforts to convert the thousands of acres of useless bog on this river into productive marsh will be entirely successful.

The best account of Toler Thompson and his work that I have seen is in an article by Judge Botsford in the *Chignecto Post* in January, 1886. Another valuable article on the history of marsh reclamation is that by Mr. Howard Trueman in the *St. John Sun* in late December, 1897.

(including the aggressive *man*). To these should be added another of great importance, *geography of the basin.*

Water.—Of all the factors determining plant form and distribution, this is the most important. We consider first the precipitation of the marsh country. No records are available for the immediate vicinity, but it may be inferred from the amount in places surrounding the region. Thus, according to the rainfall map published in 1899 to illustrate the presidential address (by T. C. Keefer) before the Royal Society of Canada, the mean annual rainfall is: at Moncton, N. B., 44.96^{in}; at Truro, N. S., 43.28; at Charlottetown, P. E. I, 41.45, while at St. John, N. B., it is 47.38^{in}. The marsh country, lying at the head of the Bay of Fundy, and directly in line with it, probably has less rainfall than St. John, but more than any of the other localities; and hence we may fix it conservatively at 45^{in}.

As to its distribution through the year, the only available records are for St. John, where it is as shown in the following table, "for a long series of years," supplied to me by the Dominion Meteorological office at Ottawa:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
5.55	3.93	3.80	2.50	3.66	2.72	3.29	4.64	3.08	4.13	4.71	5.16	47.17^{in}

Diminished *pro rata* for the lesser total rainfall, this table represents proportionally, no doubt, the distribution of precipitation through the year at the marshes.

It thus appears that the marshes have a precipitation ample for the development of an abundant temperate-region vegetation, and that it is distributed fairly evenly through the growing season of the year.

As to prevailing humidity of the atmosphere, there are no records available even at St. John. But since there is much cloudy weather, no little fog and mist, almost insular conditions, and very constant southwest winds blowing over the entire length of the Bay of Fundy, the humidity must be rather high.

Turning to the influence of water in another way, its mechanical effects, several points are to be noted. One is the very impor-

tant result arising from the abundant precipitation in connection with the poor drainage, leading to the formation of the immense bogs later to be considered. The presence of ground water in soil is usually important, but it here plays little or no part, as will be pointed out later. Another effect is in the scattering of seeds by means of currents. It would seem that the tidal currents in the rivers must form efficient disseminators of the seeds of at least the salt-plants. I have made a test of this by bringing back from the marshes several samples of the newly-deposited marsh mud, which the next spring were given very favorable conditions for the germination of any seeds in them, but no plants appeared. It may be that none were present in summer, and autumn samples might give a different result. There is, however, another mechanical effect of the tidal currents of considerable importance, namely, although they have built up the marshes entirely, they keep the river banks so constantly shifting, laying down mud in some places and scouring it out in others, that no vegetation is able to gain a foothold below the quieter zone near high-tide marks, excepting in the case of the curious sedge bogs, which I do not entirely understand; and these great banks are bare of all plant life excepting an occasional diatom swept from the sea. These banks and flats must be the largest areas barren of life in all northeastern America.

Temperature.—Next in importance to moisture as an ecological factor, is temperature. I have been unable to secure a copy

	January	February	March	April	May	June	July
Mean highest	28.2	27.6	34.3	46.4	57.2	64.4	68.8
Mean lowest	9.0	9.7	18.3	30.8	40.4	48.3	53.2
Mean temperature	18.6	18.7	26.3	38.6	48.8	56.3	61.0
Mean daily range	19.2	17.9	16.0	15.6	16.8	16.1	15.6
Absolute highest	50.0	49.0	52.0	71.7	75.0	86.7	88.9
Absolute lowest	−21.0	−15.0	−10.0	12.0	27.0	35.0	41.0

	August	September	October	November	December	Year
Mean highest	68.8	63.3	51.8	43.3	32.4	48.9
Mean lowest	53.7	47.8	37.6	28.9	15.1	32.7
Mean temperature	61.3	55.6	44.7	36.1	23.7	40.8
Mean daily range	15.1	15.5	14.2	14.4	17.3	16.2
Absolute highest	85.0	85.0	72.4	61.0	54.5	88.9
Absolute lowest	43.0	32.5	21.4	− 1.5	−19.5	−21.0

of the records kept in Sackville in the marsh country, and must turn therefore to those of St. John. The above table, based on the averages for a long series of years, is supplied by the Dominion Meteorological Office at Ottawa. Owing to well-known local conditions, the summer temperatures average lower, and the winter higher at St. John than elsewhere in the province, and this correction must be applied to the table to make it of use in estimating the conditions of the marsh country.

It is important to note further, that on the marshes themselves the snowfall is said not to be great, and often for considerable periods in winter the ground is bare. This condition, combined with the strong winds that prevail there and the total lack of shelter on the marshes, makes the winter conditions unusually unfavorable for vegetation, which must consist of plants able to endure such trying conditions. For this no arrangement is better than that of the grasses, which largely retreat to or under the ground in winter. On the other hand, at times in summer, the marshes, lying at sea level and completely unshaded, receive so strong an insolation as to become very hot, though this is never long continued.

Light.—The latitude of these marshes is 45° 50′ to 46°, from which the amount of light they would receive if unshaded by clouds, etc., and with a clear atmosphere may be estimated. But the full amount is much diminished by cloudy weather. No records of cloudiness are kept nearer than St. John, where the percentages for a long series of years are as follows:

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
53	54	60	55	61	62	63	62	53	58	60	59	58

Probably the cloud percentage for the marshes is not very different from this, though it would be less rather than more, say 50 per cent. for the year, 55–60 per cent. for the summer months. No records whatever for intensity of the light are available. It is important to note, however, that the marshes, perfectly level and unshaded, receive the full value of what light there is.

Air.—Here as elsewhere, chemically the air is hardly an ecological factor; at all events it is not a differential factor. Atmospheric pressure on the marshes, lying at sea level, is of course at its maximum, but the daily fluctuations of the barometer, as Schimper remarks, have no known effects upon the form or distribution of vegetation. Mechanically, however, as it moves in winds, the atmosphere is here important. Unfortunately no official meteorological records are available for direction or velocity, but a record of another kind is visible and unmistakable, namely, the wind effects upon the vegetation. As I have elsewhere pointed out,[22] the trees and shrubs on the neighboring ridges and in places on the margins of the bogs are strongly bent to the northeast, and show a great development of branches on that side, with an abortion on the southwest. This is caused by the very strong southwest winds which prevail here, as the residents agree, during most of the year, a phenomenon resulting from the position of the marshes in relation to the Bay of Fundy. This great bay lies northeast and southwest, and is of the form of a huge funnel. Wide at its mouth, it narrows between walls of increasing height (300 to 700 feet or more) towards its head. At Cape Chignecto the northern branch, with which we are concerned, continues and even intensifies this funnel character, ending finally in the low-lying marsh country. The great winds here are due to very much the same causes as the great tides. Every wind from a southerly direction is thus brought into a southwesterly course, condensed, strengthened, and poured over the low-lying marsh country, and the vegetation must be of a kind to endure it, for which nothing is better than the grasses.

It might be expected, as a result of the prevalence of these winds, that dunes would be formed on the unreclaimed marshes. There is, however, not the least trace of this, chiefly because the mud when laid down by the tide hardens as it dries, allowing the wind no hold upon it.

The constancy and strength of the winds on the marshes must greatly promote evaporation (transpiration) from any

[22] Bull. Nat. Hist. Soc. New Bruns. 4:134.

vegetation there, not only in the summer, when an abundance of water is usually available for the vegetation, but in those critical periods of winter and early spring, when, owing to the low temperature of the soil, water is not readily absorbed.

Another important influence of wind upon vegetation consists in its effects upon cross-pollination and dissemination. Obviously the conditions are particularly favorable for wind-pollination on the marshes (and by that very fact somewhat unfavorable for insect-pollination), and the same is true for wind dissemination. We shall see later how much the vegetation is influenced by these factors.

[*To be continued.*]

GEOGRAPHIC DISTRIBUTION OF ISOETES SACCHARATA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LI.

GEORGE HARRISON SHULL.

(WITH MAP)

WHILE making a study of the aquatic vegetation of Chesapeake Bay for the U. S. Bureau of Plant Industry during the summer of 1902, I located several new stations for *Isoetes saccharata* Engelm. This species has had an interesting history, and as our knowledge of its range has greatly increased within the last few years, I have thought it desirable to publish the accompanying map showing the exact distribution as now known, to give a detailed account of its history, and to discuss briefly several problems which have presented themselves for solution.

For a quarter of a century *Isoetes saccharata* Engelm. was known only from its type locality on the Wicomico River and from the Nanticoke, which empty into the bay by a common mouth opposite and a little north of the mouth of the Potomac. Far up the Wicomico, about a mile below the town of Salisbury, Maryland, the plant was first discovered by William M. Canby in 1863. The material was submitted to Dr. Engelmann, who was at that time the highest American authority on the genus, and was first described by him in Gray's *Manual*, 5th edition, p. 676, 1867. In 1874 Canby found a second station at Seaford, Del. Not until 1888 was it collected at a third station, when it was found by Vasey and Coville near Alexandria, Va., in Hunting Creek, a tributary to the Potomac. The material obtained here was not recognized for some years as identical with Canby's material, and was referred by Theo. Holm to *Isoetes riparia* Engelm.[1] The next year Coville found it at Mount Vernon on the Potomac, but this collection seems to have been overlooked

[1] Proc. Biol. Soc. Washington 7:132. 8 Ap 1892.

by Holm, and was not published until in 1900, when it was mentioned in the *Sixth List of Additions to the Flora of Washington*.[2]

Not until 1893 were specimens recognized as *Isoetes saccharata* Engelm. secured away from Canby's stations on the Wicomico and Nanticoke Rivers. In this year T. Chalkley Palmer discovered it near the western end of the Delaware and Chesapeake Canal in Back Creek, a tributary to Elk River, nearly 140^{km} north of the type locality. During the next two years he discovered it at several other points in both Elk and Sassafras Rivers. These collections formed the subject of an interesting account published in the BOTANICAL GAZETTE in 1896.[3]

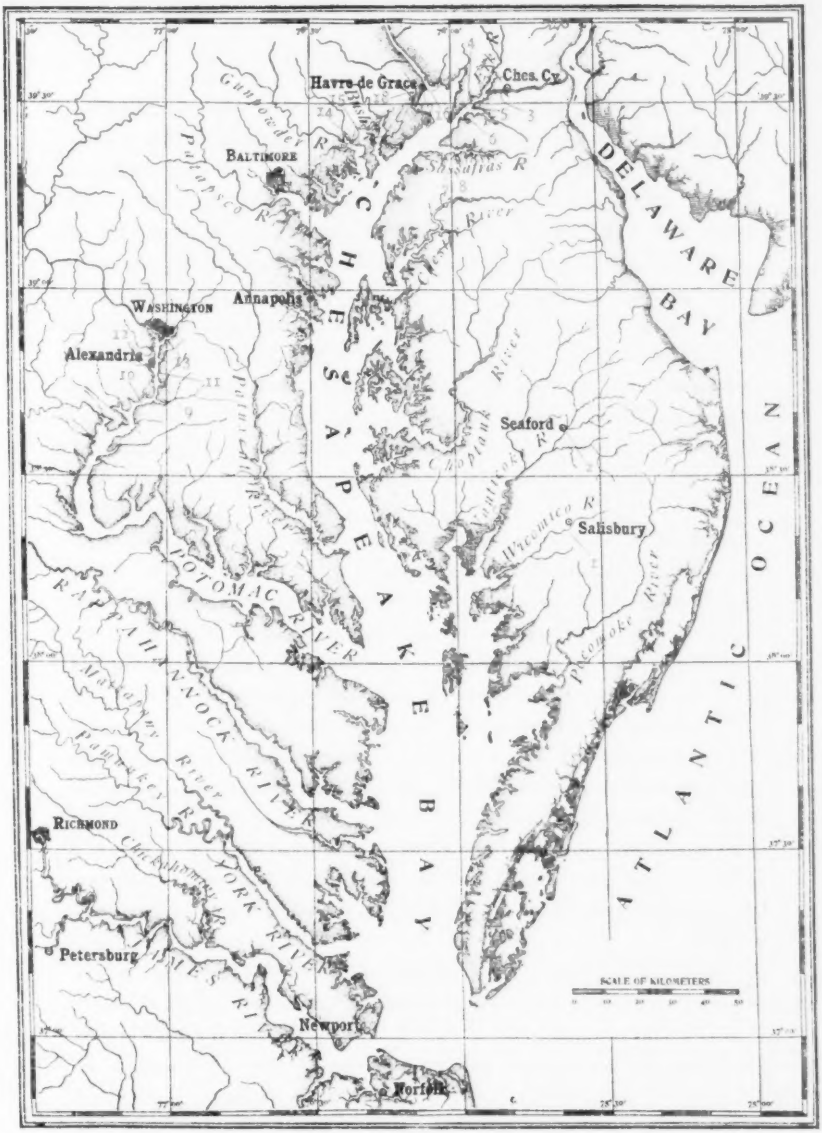
The only new stations which have been published since Palmer's account are given in the *Sixth List of Additions to the Flora of Washington*,[4] where, besides the reference to Coville's Mount Vernon station above mentioned, two new localities are recorded for the upper Potomac. Along with the publication of these stations were given the descriptions of two new varieties: var. *Palmeri* A. A. Eaton, based upon Palmer's material from Lloyds Creek, Sassafras River; and var. *reticulata* A. A. Eaton, based upon several collections, including that of Vasey and Coville (1888) from the Hunting Creek station, Alexandria, Va.

Since the publication of Palmer's paper on Isoetes, that collector has located several new stations which are here published for the first time. The most notable of these, and the only one outside of the Elk and Sassafras Rivers, is about 25^{m} north of the Havre de Grace light at the mouth of the Susquehanna River, and therefore at the very head of the bay.

I believe these are all the localities known for the species before my collections of the past summer. My work was limited almost entirely to the west side of the bay, and my collections of *Isoetes saccharata* were made in the western tributaries and along the shore of the northern part of the bay, my most northern station being only 500^{m} from Palmer's Havre de Grace station, thus making the circuit about the head of the bay virtually complete.

[2] Proc. Biol. Soc. Washington **14**:49. 19 Je 1901.

[3] BOT. GAZ. **21**: 218–223. 1896. [4] *Loc. cit.*



EXPLANATION OF MAP OF CHESAPEAKE BAY.—Adapted from Coast Chart number 376 of U. S. Coast and Geodetic Survey, and McGee's Drainage Map of the Middle Atlantic Slope (U. S. Geol. Survey, Seventh Annual Report, *pl.* 57.) Stations for *Isoetes saccharata* Engelm. are located at the points in which the index lines cut the shore lines.

So far as could be determined, the index lines are perpendicular to the portion of the shore occupied by the Isoetes.

It will be seen then that within the last ten years *Isoetes saccharata* and its forms have been traced from its original station completely to the head of the bay. Wicomico River is yet the most southern station known, but it is not improbable that a careful exploration will result in its discovery in the fresh-water estuarine portions of the more southern tributaries of the bay.

For the sake of completeness and to facilitate further study of the several colonies now known, as well as to serve as an index to the map, I insert the following list comprising all the known stations, with such data as I have been able to gather regarding each. The figure preceding each name agrees with the corresponding station as indicated on the map. In each case the station is at the point in which the index line intersects the shore line.

1. *Salisbury, Md.*—On a label in the herbarium of G. Engelmann, St. Louis, Mo., now in the Missouri Botanical Garden, the type locality is described thus:[5] "Shores of Wicomico River, one mile [1.6^{km}] below the town of Salisbury, eastern shore of Maryland, on gravel, covered by a thin layer of mud deposited by the tide; alternately covered and exposed by the tide. . . . . Growing in the society of *Sagittaria pusilla* (*S. subulata* [L.] Buchenau), *Tillaea simplex* (*T. aquatica* L.), *Hemianthus micranthemoides* (*Micranthemum micranthemoides* [Nutt.] Wettst.) etc.; first found Sept. 15, 1863. Wm. M. Canby." This label, which bears the date September 8, 1866, evidently belongs to a type specimen. In a letter to the writer, Canby explains that the original station is a sandy or gravelly slope on the south side of the river.

In September 1895 T. C. Palmer, in an attempt to visit the type locality, found the species growing at Williams Point on the Wicomico River.

2. *Seaford, Del.*, is situated at the confluence of the north and south branches of the Nanticoke River, and only 5^{km} below the head of tide water. A label in the Engelmann herbarium,

[5] A similar but somewhat ambiguous description of the type locality occurs in Engelmann's paper on "The Genus Isoetes in North America." Trans. St. Louis Acad. Sci. 4: 382. 1882.

belonging to one of the original specimens from this station reads: "Muddy and gravelly shores of Nanticoke River near Seaford, Delaware. Wm. M. Canby, Wilmington, Del., August 1874." That this was the first collection at this station is shown by the fact that duplicates in the U. S. National Herbarium and in the Herbarium of the Field Columbian Museum bear the statement that it is "a new station." The area occupied by Isoetes at this place is located "nearly opposite the town, a little above it, in fact. The space there is not very large, perhaps 100[ft]"[6] (30[m]).

3. *Back Creek*, tributary to Elk River, eastern shore of Maryland. This station is on the south shore of the creek about 3[km] from the western end of Chesapeake and Delaware Canal and nearly 1[km] below Chesapeake City. The first collection was made by T. C. Palmer in August 1893. He made further collections the following year and published a short statement in the BOTANICAL GAZETTE.[7]

4. *Piney Creek Cove* is a broad indentation in the north shore of Elk River 9–11[km] from its mouth. On August 13, 1894, T. C. Palmer collected *Isoetes saccharata*, just below the mouth of the small stream which empties at the northeast angle of the cove. This station was also mentioned with the last in the BOTANICAL GAZETTE.

5. *Town Point* is the upper angle formed by the confluence of Bohemia River with Elk River, into which it flows from the east. About 500[m] north of this point Isoetes was collected on July 31, 1896, by T. C. Palmer. A specimen from this collection in the National Herbarium gives the habitat: "Tidal tract; gravel nearly bare." This station has not been previously recorded.

6. *Cabin Johns Creek* empties into Elk River from the southeast about 5[km] above the mouth of the latter. A specimen in the National Herbarium bears the data: "July 21, 1896. Cabin John's Creek, Elk River. Tidal tract; gravel covered with mud. Collector T. Chalkley Palmer." This collection has not been published heretofore.

7. *Lloyds Creek* is a large shallow cove on the south shore of

[6] William M. Canby, in a letter. [7] BOT. GAZ. **20**: 32. 1895.

the Sassafras River, about 6[km] east of Howells Point, and is nearly cut off from the river by a sand spit. On the south shore of this shallow bay, almost due south of its mouth, a very interesting collection of Isoetes was made by T. C. Palmer, August 12, 1895. The habitat as described on a label in the National Herbarium is characterized by "reddish sand capped lightly with mud." The material departed in a marked degree from typical *I. saccharata* Engelm., as was pointed out in the collector's interesting contribution in the BOTANICAL GAZETTE in 1896 (*l. c.*). In 1900, A. A. Eaton made this material the basis of his new variety *I. saccharata Palmeri.* In a letter to the writer, Palmer states that at none of his other stations does the Isoetes grow in such abundance as at Lloyds Creek.

8. *Turners Creek* empties into Sassafras River from the south about 4[km] east of Lloyds Creek. On the south shore of Sassafras River just below the mouth of Turners Creek, a station, published here for the first time, was located by T. C. Palmer, July 18, 1897.

9. *Hunting Creek* empties into the Potomac River from the west immediately south of the city of Alexandria, Va. The highway from Alexandria to Mount Vernon is graded for some distance into the shallow part of the creek from each side, and crosses the middle part by a long bridge. The original station is a gravelly bed near the bridge on the right side of the embankment as the bridge is approached from the Alexandria end. The first collection at this place was made by George Vasey and F. V. Coville, July 22, 1888. It has been visited several times since, a recorded visit[8] having been made by W. R. Maxon, September 22, 1900. Maxon also collected at this station, September 7, 1901, a specimen of this date being placed in the National Herbarium. The writer secured specimens from the same place August 11, 1902, and also found it on the same side of the embankment which leads from the opposite end of the bridge toward Mount Vernon. These areas are not large, but the material is fairly abundant. The soil consists of pebbles covered with a layer of mud and the principal companion plant

[8] Sixth List of Additions to the Flora of Washington. *Loc. cit.*

is *Eriocaulon septangulare* With. The material collected at the Alexandria end of the bridge by Vasey and Coville, and Maxon's 1900 collection along with Steele's Anacostia material, soon to be mentioned, were made the basis of the new var. *reticulata* A. A. Eaton.

10. *Mount Vernon, Va.*, is on the west bank of the Potomac about 11 km south of Alexandria, Va. A specimen in the National Herbarium, collected at this place, bears the data: "Mt. Vernon, Va., July 4, 1889. Shore of the Potomac at the foot of the Mt. Vernon estate, Collector F. V. Coville." The collector describes (*in litt.*) the station as being "at the slope immediately in front of the house and therefore a hundred yards or more (100 m) north of the boat landing. There was a considerable area here in shallow water covered with Isoetes. The soil was gravelly."

11. *Notley Hall, Md.*, is on the east shore of the Potomac River, nearly opposite the mouth of Hunting Creek, Alexandria, Va. A specimen in the National Herbarium was collected at this place by F. V. Coville in 1894.

12. *Four Mile Run, Va.*—This creek enters the Potomac from the west about midway between Washington, D. C., and Alexandria, Va. Its lower course forms a wide bay, along the south side of which the banks are being eroded by wave action, which carries away the finer material, leaving a gently sloping tide-beach of mingled sand and gravel, on which Isoetes grows luxuriantly. The first collection at this station was made by E. S. Steele, August 5, 1898. The writer visited this place and made collections on August 22, 1902.

13. *Anacostia River* crosses the District of Columbia east of Washington, D. C., and empties into the Potomac River just south of that city. On September 1, 1900, E. S. Steele discovered Isoetes "on the southeast bank of the Anacostia River nearly opposite the Navy Yard, perhaps a half [one-fourth] mile below the Navy Yard bridge."[9] This collection forms a part of the type material of var. *reticulata* A. A. Eaton.

14. *Sugar Loaf Creek* is a small stream which empties into Gunpowder River, western shore of Maryland, from the north,

[9] In a letter to the writer.

at a point about 600^{m} northeast of Gunpowder station on the P. B. & W. R. R. On the small rounded point between Sugar Loaf Creek and Gunpowder River, I found *Isoetes saccharata* on September 2, 1902. The specimens were abundant but of small size, owing to the fact that they grew in a moderately dense colony of *Scirpus americanus* Pers., among which I have rarely found Isoetes elsewhere. Other associates of Isoetes at this station were *Lilaeopsis lineata* (Mx.) Greene, and *Eriocaulon septangulare* With. The soil conditions were typical—gravel covered with a thin layer of mud.

15. About 500^{m} above the mouth of Sugar Loaf Creek, on the east shore of Gunpowder River, I located another colony of Isoetes the following day, September 3, 1902. The specimens at this place were growing in a bed of sand only a few square meters in extent and were very thrifty.

16. *Havre de Grace Light* is on a small point on the west shore of the Susquehanna River at its mouth. The most interesting of T. C. Palmer's unpublished stations for Isoetes is a small area just north of this light house, near the pier. His collection at this point was made August 17, 1898, and is at present the northern known limit of the species.

17. *Havre de Grace Park* is along the shore of the bay, southwest of the Havre de Grace light. It descends to the bay by a steep bank, and below this bank, among the pebbles which pave the beach, I found the species growing abundantly, July 19, 1902.

18. Nearly 1^{km} west of the last, on the curved shore, known as the "knee" of the bay, *Isoetes saccharata* also grows, though not in such abundance as at the park station. I collected at this place also July 19, 1902, this being my first collection.

x. By this sign I have marked two points on Bush River at which single small specimens were found. The fact that these two specimens were seen indicates that its absence in notable quantity is due to unfavorable habitat, and not to barriers to its entrance. Although Bush River was explored from its mouth almost to the head of tide water, I did not see a single spot where I really expected to find it. The specimens found were evidently

choked by the density of the *Scirpus americanus* Pers., among which they grew. Where the shores were free from Scirpus, as they were for stretches north of Bush River station, P. B. & W. R. R., and at the mouth of Otter Creek, they were composed of pure gravel, subject to shifting with the action of the waves.

y. I have indicated thus the location of a well-grown specimen found floating in the bay at the mouth of Furnace Creek over 3 km from the nearest known colony.

It appears from this list of known stations that *Isoetes saccharata* has a general distribution in the fresh water portions of Chesapeake Bay and its tributaries, but is at present unknown from any other locality. If it has a wider distribution, our ignorance of that fact is not entirely due to lack of observation, for Delaware Bay, which furnishes the most accessible suitable habitats, has been explored by students of the genus, with the result that several stations have been located for *Isoetes riparia* Engelm., but not a single specimen of *I. saccharata* Engelm. has been found.

If the last named species is indeed limited to Chesapeake Bay, it will be of interest to consider the causes to which the restriction may be due. Endemic species have a peculiar interest in their bearing upon problems of biogeography. A cosmopolitan distribution is evidence of a high degree of adaptability to variation of habitat, and is also evidence either of an old species or of efficient means of dispersal. On the other hand, a species which is limited to a single locality is either a remnant of a once more widely distributed form, or it is a relatively new species which has arisen in the more or less isolated region to which it is now limited. In the first instance it has been protected by the barriers which surround it, or by peculiarly favorable conditions for its growth from the extinction which has overtaken the species in other regions; in the second case it has been prevented by barriers from spreading beyond the region of its origin. Cosmopolitan species seem to deny the existence of barriers, while local species not only confirm their existence but give a clue to the nature and position of these barriers. As biogeography has to do preeminently with barriers, it is evident

that species of local range are of the greatest importance in solving the fundamental problems of geographic distribution.

From this brief discussion it will be seen that there are two essentially different kinds of endemism. In one the species is a remnant, in the other it is a beginning. To the former of these the term *relict* endemism has been applied;[10] to the latter I shall apply the term *initial* endemism.[11] Relict endemism is illustrated by such classic examples as the Sequoia of western North America and *Ginkgo biloba* L. of eastern Asia. Initial endemism is perhaps best exemplified by numerous endemic species of oceanic islands, though it does not follow that all endemic species of oceanic islands are initial.

It is obvious that many difficulties will be encountered in determining whether any local species in question is a relict or an autochthon. It is also obvious that we may have initial species of a relict genus, though not the reverse. After examining the nature of the barriers which limit the distribution of *Isoetes saccharata* I shall suggest to which class of endemic species it probably belongs.

It will have been noted in examining the map, or in looking over the descriptions of the several stations, that even within the narrow confines of Chesapeake Bay, this species is not generally distributed along the shores, but occurs only here and there in closely limited areas, the largest of which is perhaps less than 100^{m} long. This extreme localization within its range is due solely to the requirements of its habitat. The chief conditions necessary for its success are the following:

a) It is limited to tidal beaches, which fact restricts it to a narrow zone, never more than a few meters wide along the shore

b) It requires fresh water, never occurring in water of more than slight salinity. South of Spesutie Island the rivers have a

[10] DRUDE, O., Handbuch der Pflanzengeographie 125. Stuttgart: J. Engelhorn. 1890.

[11] An initial species is called an autochthon and *autochthon* endemism might be used in contradistinction to *relict* endemism. Drude (*op. cit.* p. 124) refers to such species as "vicarious or corresponding forms," from which initial endemism is sometimes called *vicarious* endemism, but the significance of vicarious in this connection is too obscure to commend its adoption.

section near their mouths too salt for the growth of Isoetes, and this salt water section of the rivers becomes longer as we proceed toward the mouth of the bay. This isolates the suitable habitats in one river from those in neighboring rivers.

c) There must be sufficient stability of the soil of the shore to resist the action of the waves, and at the same time sufficient fineness of the soil particles to supply the needs of the plant without requiring an extensive root system. With one exception all the colonies visited by me grew on beaches characterized by rather coarse gravel set firmly in a matrix of sand, and covered over with a thin film of mud. The exception was found at my upper station on Gunpowder River, where a small but unusually luxuriant colony grew in a bed of sand. In this place the shore was protected from severe wave action by a zone of *Zizania aquatica* L., and I have no doubt that this circumstance alone made it possible for Isoetes to retain its hold at this place.

In Engelmann's manuscript notes, the following statement is accredited to William M. Canby: "I don't find any Isoetes (*riparia*, *Engelmanni*, *valida*, or *saccharata*) in pure mud or pure gravel; they always grow in mud which is deposited on gravel beds either by the tides (*riparia* and *saccharata*) or by rains which wash it down (*Engelmanni* and *valida*)."

d) *Isoetes saccharata* also requires that competition with other plants be slight. It is never found forming colonies of such density that it crowds itself, and its most frequent companion species have the same scattered habit. Only at my lower station on Gunpowder River have I found an exception to this. Here it is in competition with *Scirpus americanus* Pers. and is evidently suffering in the conflict. It would no doubt be entirely excluded by the Scirpus if the latter were as robust and densely set as is usual for that species on fresh water beaches.

When we consider the number of apparently essential elements in its habitat and the fewness and smallness of the areas in which all these elements are present, it is easy to understand the extreme localization of the species. But every restriction of habitat increases the difficulty of successful dispersal, and we may well ask how the species has succeeded in finding the places, often

so widely separated, which are adapted to its successful growth. Not only are difficulties presented by the requirements of its habitat, but there are factors in the life-history of *Isoetes saccharata* which are not favorable to rapid dissemination over wide areas. Heterospory is one of these. If spores are carried by any agency, microspores and megaspores must be lodged at the same place or the sporophyte itself must be carried. Besides, there seems to be a tendency in the species to dioecism,[12] and in proportion as this tendency is manifest the difficulties of dispersal are increased.

The means of dispersal upon which this and other species of like habitat may depend are several. The most important means must always be the water currents, because these are always acting at the time and place of spore production. Moreover, the chances are very good that the spores so carried may be lodged along some shore line where a new colony may be formed. In times of storm the waves may tear up whole plants from their anchorage in the littoral gravel and carry them far away to leave them finally stranded on some beach which may be adapted to the growth of the spores thus transported. Late last summer the writer saw a thrifty specimen of *Isoetes saccharata* floating in Chesapeake Bay, 100^{m} east of Stump's Point, at the mouth of Furnace Creek at the head of the bay, over 3^{km} from the nearest known station for the species, though possibly much nearer to some unknown station.

It is conceivable that biotic agencies might also occasionally serve as means of dispersal. Especially, from the observations of Charles Darwin and others, we might expect birds which frequent the shores to carry the spores occasionally on their feet or on their beaks, and as they move from one shore line to another, the spores so carried would be left in a new place favorable to growth. A. A. Eaton (*in litt.*) tells me that ducks are exceedingly fond of the spores of Isoetes, and that the lamellae of their beaks are especially fitted to retain them until washed

[12] PALMER, T. C., 1896, *loc. cit.* A. A. Eaton looks upon dioecism in this species as of rare occurrence, in which case it would be of slight importance in this connection.

out in another locality, and he thinks that this has been perhaps the efficient means of their dispersal.

A third possible method of dispersal is transportation of spores by the wind, but it is evident that successful dispersal by this means must be very rare. In the first place, the wind could only secure spores to carry after they had been stranded on the shore at high tide or in times of storm. Besides, the winds almost invariably blow across the shore line instead of parallel with it, so that the likelihood of the spores being stranded in a place adapted to their development is very slight indeed.

As the distribution of *Isoetes saccharata* appears to be limited by the confines of Chesapeake Bay, while the agency of birds and of the wind are not so limited, these agencies must be assumed to be relatively inefficient. For, if the waterfowl provided efficient means of dispersal, we should expect to find the species following the chief lines of migration as far as there were suitable habitats for its growth. As these lines of migration run parallel with the Atlantic coast, this would specially favor the transportation of *I. saccharata* into Delaware Bay and of *I. riparia* Engelm. into Chesapeake Bay. Our failure to find evidence of any such transportation is peculiarly striking when we bear in mind that the Back Creek station for *I. saccharata* is but little more than 16 km distant from the nearest point on Delaware Bay, while the known stations on Chesapeake Bay are in some instances separated by distances of more than 80 km.

We must conclude from these facts,[13] I think, that water currents supply the only efficient means of dispersal for this species, and that these have supplied the means by which new colonies have sprung up in more or less distant areas. But even water currents could scarce be adequate to carry the spores from one

[13] This entire discussion is based on the assumption that *Isoetes saccharata* and *I. riparia* are really distinct species, as they have always been considered. In some of its forms *I. saccharata* approaches so nearly to *I. riparia* that the suggestion is not far that they are ecological varieties of the same species. Too little is known, as yet, about ecological varieties, to make more than a suggestion permissible. It is obvious that successful transportation from the one bay to the other may have taken place any number of times, if in each case the ecological conditions were such as to produce from the spores of a single specimen, *I. riparia* in Delaware Bay and *I saccharata* in Chesapeake Bay.

station to the mouth of the river in which it occurs, thence up or down the coast to a neighboring river, and up that river to the fresh-water portion near the head of tide water. Such a transportation, if at all possible, must depend upon the most exceptional of circumstances.

Probably a truer explanation is found in relation to the geological history of the bay. It is believed by some geologists[14] that the region about Chesapeake Bay is now sinking, and it is certain that it has recently sunk after a period of elevation. In fact, it seems to have been elevated and depressed several times in its Pleistocene history.[15]

The position of old shore lines with their sea cliffs and terraces gives evidence of the amount of subsidence of the land at each period of sinking, but no evidences remain as to the height to which the land rose during each period of elevation. The present elevation of the land is such that the water of the bay is fresh to Spesutie Island, about ten kilometers below the mouth of the Susquehanna River. During periods of greater elevation the water was fresh further to the south. When the land was so elevated that the water was fresh at the mouth of the Potomac River, favorable habitats along the shore of the bay must have been occupied by the progenitors of the *Isoetes saccharata* colonies which now occur in the upper estuarine portion of the tributary rivers. As the land sank and the rivers were ponded farther and farther from their mouths, new areas became adapted to the growth of Isoetes, and new colonies were formed. Simultaneously the colonies furthest down stream were destroyed by the advance of salt water. In this way there came to be, instead of a single colony or group of colonies at the head of Chesapeake Bay, as many distinct colonies as there were ponded tributaries. So long as the land continued to sink, the successful reproduction was on the up-stream side, and destruction followed *pari passu* on the down-stream side until the present condition of widely separated colonies was brought about. In periods of

[14] COOK, GEORGE H., Geology of N. J. **1868**: 343 *et seq.*

[15] MCGEE, W J, Am. Jour. Sci. **35**: 463–466. 1888. DARTON, N. H., Bull. Geol. Soc. Am. **2**: 450. Ap 1891. SHATTUCK, GEORGE B., Am. Geol. **28**: 100–105. Ag 1901.

elevation, the reverse process must have taken place, and the many distinct areas must have been merged again into one. This may have taken place as often as the bay has been up and down, and certainly has happened as often as the bay has risen and fallen since *Isoetes saccharata* entered it.

Just how or when Isoetes entered Chesapeake Bay is, of course, impossible to say, except that, according to this hypothesis of its dispersal, it must have been introduced before the last sinking of the coastal plain.

From what has been said of the requirements of its habitat and the means of dispersal of Isoetes, it will be seen that the barriers between Chesapeake Bay and Delaware Bay and between both of these and other fresh tidal waters, are of such definite character as to render these bays virtually islands of water in oceans of land. As we find *Isoetes saccharata* nowhere else than in Chesapeake Bay and *Isoetes riparia* nowhere else than in Delaware Bay, it seems fair to assume that neither of these species ever existed as such outside of the body of water to which it is now limited, and that we have here examples of initial endemism entirely comparable with that so common upon oceanic islands.

These two species are closely related and probably stand to each other in relation of parent and offspring; but which is the parent and which the offspring may not be easy to decide. Or perhaps they were the offspring of a common parent different from both. The nearness of this relationship was emphasized in the recognition of the two varieties, *Isoetes saccharata Palmeri* A. A. Eaton and *I. saccharata reticulata* A. A. Eaton, both possessing characters intermediate between *Isoetes saccharata* Engelm. and *Isoetes riparia* Engelm. The significance of these forms will be increased rather than lessened if they should prove to be untenable as varieties. For if these varieties are shown to be simply stages in the development of a polymorphic species, the greater range of variability which must then be admitted as a character of *I. saccharata* Engelm., coupled with the fact that those variations in several different features are in the direction of *Isoetes riparia* Engelm., would make almost certain the inference that an extreme variation of *I. saccharata* had become somewhat fixed through its isolation in Delaware Bay.

Careful cultures will be necessary to demonstrate conclusively the polymorphism of *Isoetes saccharata* Engelm., but that seems at present the most satisfactory explanation of the following facts. My attention was called both by A. A. Eaton and T. C. Palmer to several futile attempts which had been made to secure *typical* material from the *type* locality. It appears that the original description was written from a form which is of very rare occurrence. Even the co-type material did not agree with the type, and the Wicomico station has been visited several times since, but no typical material has been secured there. The infrequency of the recurrence of the typical form is well shown by the fact that my collection from Hunting Creek, Va., appears to be the first material collected since 1863, which agrees in its spore characters with the type material. The striking fact here is that my collection of typical *I. saccharata* Engelm. came from the type locality of variety *reticulata* A. A. Eaton. This colony is only a few square meters in extent and a considerable number of specimens had been collected there by Vasey and Coville in 1888, and by W. R. Maxon in 1900 and 1901. Every one of those specimens appear to have been var. *reticulata*. I collected at the same place perhaps a dozen specimens, every one of which was typical *I. saccharata*. The only plausible explanation of these facts, it seems to me, is that the identical plants which had been var. *reticulata* at the time of the previous collections, were last year typical *I. saccharata*.

Another similar circumstance which lends support to this explanation is that E. S. Steele's collection at Four Mile Run in 1899 was nearly typical *I. saccharata*, whereas the considerable number of specimens secured by me in 1902 from the same spot, all showed extremely well-marked characters of var. *reticulata* A. A. Eaton.

I have no such striking facts against the validity of var. *Palmeri* A. A. Eaton, since I visited no *Palmeri* station, but much of my material from the head of the bay was intermediate between *I. saccharata* and var. *Palmeri*, as was also Coville's Mount Vernon collection. T. C. Palmer found the same conditions at Cabin Johns Creek and Town Point in Elk River. If

Isoetes saccharata should prove to be polymorphic, as these facts suggest, the result will be of interest in its bearing upon such species as *I. echinospora* Durieu and *I. velata* A. Br., whose numerous intergrading forms have proved so baffling to systematists.

By way of summary, then, *Isoetes saccharata* Engelm. has been located in a number of tributaries of Chesapeake Bay from the the Potomac and Wicomico Rivers to the head of the bay.

The species is conceived to be autochthonous in Chesapeake Bay, and to bear toward *Isoetes riparia* Engelm. the relation of parent to offspring.

Its present distribution is explained by the geomorphic movements of the coastal plain.

Certain facts are presented which suggest that the species is polymorphic, and that the varieties *Palmeri* A. A. Eaton and *reticulata* A. A. Eaton are untenable.

I take pleasure in acknowledging my indebtedness to Wm. M. Canby, F. V. Coville, T. C. Palmer, E. S. Steele, and W. R. Maxon for notes on their several collections of *Isoetes saccharata* Engelm. and its forms; to Dr. J. N. Rose for data from U. S. National Herbarium, and Dr. Wm. Trelease for data from the Herbarium of the Missouri Botanical Gardens, and from G. Engelmann's manuscript notes; also to Miss Veva M. Brower for notes on the Nanticoke River at Seaford, Del. But I am under special obligations to A. A. Eaton, who has kindly examined all my material and has encouraged me with suggestions and criticisms on the discussions involved in this paper. To all of these I wish to express my sincere thanks.

THE UNIVERSITY OF CHICAGO.

A SKETCH OF THE FLORA OF SOUTHERN CALIFORNIA.

S. B. PARISH.

THE name "Southern California" is here restricted to a territory somewhat less extensive than that to which it is sometimes applied; but even as here limited, to the five southernmost counties—Los Angeles, San Bernardino, Riverside, Orange, and San Diego—it includes one quarter of the area of the whole state, and exceeds in size the great state of Ohio. It has an area of 40,889 square miles (over 100,000 sq. kilometers). Its greatest breadth, from north to south, is 210 miles (336 km), and from east to west 282 miles (451 km). It lies between 32° 30′ and 35° 40′ north latitude, and between 37° 15′ and 42° longitude west from the meridian of Washington. Its western boundary is formed, for the greater part, by the Pacific Ocean, but partly by the counties of Ventura and Kern, and these two counties, together with Inyo, bound it on the north, while for a short distance on the northeast it touches the state of Nevada. The river Colorado separates it on the east from Arizona, and on the south it adjoins the Mexican state of Lower California.

Before proceeding to a consideration of the flora of this region it is desirable to speak briefly of the physical character of its surface, and of its climate, since these are the most important influences by which the development and distribution of its plant population have been determined.

OROGRAPHICAL FEATURES.

The region is one of mountains, whose ramifications embrace numerous valleys of greater or less extent. The main axis of upheaval is a continuation of the Sierra Nevada. It enters our region at Ft. Tejon, in which neighborhood the Coast Range unites with it; and it extends in a course from northeast to southwest, culminating in the twin summits of San Bernardino and Grayback, respectively 10,100 ft (3,080 m) and 11,725 ft

(3,575 m) above sea level. The mountains between these limits are generally called the San Bernardino Range.[1] It is made up of the Sierra Liebre and Sierra Pelona, between Tejon and Soledad Passes; the San Gabriel Mountains, with the peaks of San Gabriel, 6,232 ft (1,900 m), San Antonio, 10,120 ft (3,085 m), and Cucamonga,[2] 6,500 ft (1,980 m), between Soledad and Cajon Passes; and the San Bernardino Mountains proper, between Cajon and San Gorgonio Passes.

North of Soledad Pass the mountains are comparatively low, but rugged and broken. An important cross range, the Santa Monica, maintaining an altitude of 2,000 to 3,000 ft (600–900 m), stretches from San Fernando Peak, 3,793 ft (1,156 m), to the Pacific Ocean at Point Duma. But south of Soledad the mountains become higher, towering up abruptly, from a valley base 500 to 1,000 ft (150–300 m) above the sea, to a ridge line having an altitude of 5,000 to 6,000 ft (1,500–1,800 m). From the desert they present a less lofty appearance, since on that side the base altitude is 3,000 to 3,500 ft (900–1,066 m).

Grayback throws out an important spur, in the direction of the main range, towards the Colorado River. This may be known as the Chuckawalla Range, although that name is often restricted to its further extremity. It separates the Colorado and the Mojave[3] Deserts.

The low San Gorgonio Pass separates Grayback from San Jacinto Mountain 10,805 ft (3,993 m), an air-line distance of some twenty miles. The mountains here spread out, their course changes, and is less defined. But regarding the line which divides the watershed draining into the Pacific from that which drains into the desert, its direction is found to be about 10°

[1] First by Blake in Pac. R. R. Rep. 5. He also suggested the name "Peninsular Range" for the mountains extending from San Jacinto into Lower California, but this name, although appropriate, has failed to find acceptance.

[2] This was a troublesome name to the early explorers. It is Quiqual Gungo of Pac. R. R. Rep. 4: 38; Quiquai-mungo *ibid.* 5²: 80; and Kikal Mungo *ibid.* 7: 8.

[3] I use the spelling long current in California. While only the Spanish orthography of an aboriginal name, it harmonizes with such Spanish names of the region as Tejon, Cajon, etc. The U. S. Board on Geographical Names has adopted the form "Mohave," but this should not be allowed to supersede a well-established local usage. The name was first printed by Fremont in 1844, who spelled it "Mohahve."

south of east. Here it is the desert face which is precipitous, its base, for the most part, not exceeding 500 ft (150 m) above sea level, while upon the other side San Jacinto overlooks a confusion of ridges and lesser peaks.

A main cross-range from San Jacinto parallels the San Bernardino Mountains at a distance of about forty miles. It comprises the Palomar Mountains[4] (summit 5,800 ft, 1,765 m) and the Temescal Mountains, whose terminal summit, Santiago Peak,[5] has an altitude of 5,675 ft (1730 m), and separates the San Jacinto Valley from the coast region.

Further south Cuyamaca Mountain, 6,500 ft (1,980 m) high, dominates a rugged region of high ridges and narrow valleys. In default of a better name the entire chain, from Tejon Pass to Cuyamaca, may be called the Nevadan Range, since it is, in truth, a part or a continuation of the Sierra Nevada.

THE DESERTS.

The topography of the desert region is less accurately known. It comprises two distinct divisions: the Colorado Desert and the Mojave Desert. The former, stretching southeastward from San Gorgonio Pass to the Mexican boundary, is a great valley, 180 miles (288 km) long, and 30 to 50 miles (50–80 km) wide. In its center it sinks into a deep depression over 250 ft (76 m) below sea level,[6] the dry bed of what has been in prehistoric times first an arm of the sea, and later a fresh or brackish lake. In this depressed area, and notably near Salton, volcanic forces yet manifest themselves in "mud volcanoes" and extensive solfataras.

The lower part of this desert, toward Yuma, and in the New River region, consists largely of pebble-covered clay plains and

[4] Also known as Smith Mountains.

[5] Sometimes called Saddleback, or Santa Ana peak. In 1861 Dr. Whitney gave it the name Mt. Downey, which fortunately has never been accepted. This whole range is often called the Coast Range, but it has no connection with the true Coast Range of California.

[6] The following are the altitudes in feet at stations on the Southern Pacific Railway where it crosses this depression: Seven Palms, 582; Indio, −20; Walters, −195; Dos Palmas, −253; Salton, −263; Flowing Well, 5; Tortuga, 185. The total distance, in a straight line, is about 80 miles (130 km).

shifting sand hills, and has an altitude of 150 to 400 ft (45–120 m). The area of the Colorado Desert has been estimated at 9,000 square miles (14,400 sq km).[7]

The Mojave Desert lies on the north side of the San Bernardino Range, and its continuing spur, the Chuckawalla Mountains; eastward it stretches to the Colorado River, and northerly to and beyond our boundary lines. Its greatest length, east and west, measured in an air-line, from Gormans Station, at the head of Antelope Valley, to the Needles on the Colorado River, is about 130 miles (210 km). Its width, north and south, from the mountains which form its southern rim to our northern boundary, varies from 30 to 60 miles (48–96 km). No estimate of its area appears to have been made. Within our limits its altitude is much greater than that of the Colorado Desert, being 2,000 to 3,500 ft (660–1,067 m), but beyond them it also sinks, in Death Valley, below sea level.

Its whole surface is cut up by short isolated ranges and "lone mountains," which are surrounded by sloping mesas, or enclose basins whose lowest portions are occupied by "dry lakes." Some of these are level expanses of hard, elastic clay, smooth and bare as a racetrack, and bordered by a narrow belt of nitrophilous vegetation. Receiving the scanty storm water that rolls down from the bare hills about them, they at times may be transformed into tenacious mud, or even be covered by a few inches of water. Or the floor of these basins may consist of what prospectors call "self-rising soil," a deep bed of loose alkaline powder, slightly crusted over, into which foot and wheel sink wearily; or, again, it may be covered with a snowy incrustation of soda salts.

The highest mountain of the Mojave Desert is Ivawatch, 6,290 ft (1,917 m), on the northern boundary of San Bernardino county. Some twenty miles southwest is Pilot Knob, 5,525 ft (1,684 m), a noted landmark, as its name indicates. Mt. Manchester, near the Needles, is 4,570 ft (1,448 m) high. But the most important of these ranges are the Providence Mountains,

[7] This is for the part of it within the United States; beyond the boundary it continues to the Colorado River and the head of the Gulf of California. Its width on the Colorado River is fully 75 miles (120 km).

situated on the eastern border of the desert, and extending some 75 miles (120 km) in a NNE and SSW course, culminating at the south in Mt. Edgar, 6,350 ft (1,935 m).

DRAINAGE SYSTEMS.

A country such as I have described, if in a region of abundant rainfall, would abound in limpid lakes, and in living streams, some of which would be of considerable volume. But far other is the case under the arid conditions which here exist. Even the streams rising in the high mountains of the San Bernardino range are infrequent, slender and inconstant; and of still less importance are those which drain the mountains to the south. In seasons of unusual precipitation they become raging torrents, and at such times the larger streams may carry their waters to the sea; but ordinarily their volume is insufficient to reach their nominal mouths, while in summer they dwindle down to thin rivulets which repeatedly sink and reappear in their wide sandy beds.

The San Gabriel Mountains give rise on their desert slopes to Rock Creek,[8] which ventures beyond their base only in wet weather. On their seaward side they are drained on the west by the Los Angeles and San Gabriel Rivers, and on the east by Lytle Creek, a tributary of the Santa Ana.

The San Bernardino Mountains furnish the waters of the most important streams of the whole region. On the northern watershed the Mojave River has its source in Holcomb Valley, at an altitude of 7,000 ft (2,134 m). It flows 75 miles (120 km) in a northerly direction, and then turning to the east continues for 60 miles (96 km) further, the distances being measured in an air line, but following its meanderings its length is fully 200 miles (320 km). In its course it disappears eight times in its sandy channel, leaving it entirely dry for long intervals, and is finally lost in Soda Lake (alt. 1,116 ft, 340 km), a flat, elliptical depression some 70 square miles (112 sq km) in area, occasionally flooded a few inches deep with water, but usually whitened with alkaline efflorescences. The eastern drainage of these mountains forms

[8] This is the "Johnson's River," of Blake, Pac. R. R. Rep. 5:30 *et seq.*

the Arroyo Blanco, or Whitewater, a strong stream which is soon lost in the sands of the Colorado Desert.

The Santa Ana River carries the seaward drainage, and has an airline course of 85 miles (136 km), in a southwest direction, to the ocean, which, it is said, its waters have been known to reach in high floods. In ordinary stages it sinks soon after disemboguing from the mountains, and reappearing after ten miles (16 km) carries more or less water nearly to Santa Ana.

San Jacinto Mountain gives rise to a stream bearing the same name, which follows a southwest course to Elsinore Lake. Its channel, however, is only intermittently supplied with surface water. The Santa Margarita, the San Luis Rey, the Sweetwater, and some lesser streams, drain the mountains of San Diego county, and have a character similar to those already described.

The Colorado River, which touches the border of the state, does not receive from it a single tributary, great or small; but an abandoned channel, the so-called New River, carries the waters of the Colorado, in times of great floods, into the southeastern part of the desert and to the Salton Sea.

GEOLOGICAL FORMATIONS.

The great mountain axis consists principally of granitic formations, and such is the prevailing character of the subordinate ranges. There are occasional outcroppings of limestones, but always of limited area. A range of Tertiary hills, conglomerates, sandstones and shales, beginning near Pasadena, stretches to the Santa Ana River, where it is divided by the granites of the Temescal Mountains, a narrow arm continuing along their northeastern base, while a wider one (10–18 miles, 16–29 km) turns toward the coast, which it reaches at San Juan, and follows it thence to the Mexican boundary. A less important Tertiary formation skirts the southern base of the San Bernardino Mountains from Santa Ana Cañon to the Whitewater, occupying an area of 30 miles (48 km) in length by 1 to 5 miles (1.6–8 km) in width. The same formation also appears in the Palos Verdes hills, and on the islands off the coast.

The San Fernando Plains, the wide expanse of fertile country

between Los Angeles and Santa Ana, the San Bernardino, San Jacinto, and many smaller valleys are Quaternary and Recent. They include sandy and gravelly mesas, as well as rich loams, ferruginous clays, and black adobe. Almost without exception they contain soda salts, from the small percentage which increases fertility, to the excess which forbids the growth of all but a few specialized plants. Recent formations also prevail throughout the Colorado Desert.

The formations of the Mojave Desert are less well known. The mountains are, for the most part, granitic, the intervening mesas and valleys being of recent deposition. Evidences of former volcanic activity are exhibited in places. This is most marked in the country between Point of Rocks and Bagdad, on the Santa Fé Railway, an air-line distance of some 80 miles (130 km). Here the rocks are metamorphosed, and often display commingled bands and patches of reds, blues, greens, purples and yellows.[9] The mesas are strewn with scoria, the hills have black lava caps, fissure lines are seen, and lava streams may be traced for miles. Not less than a dozen volcanic cones are known in this region. One of the largest is 450 ft (137 m) high and 3,000 ft (914 m) in diameter at base; the extinct crater at the summit is 750 ft (228 m) in diameter and 150 ft (45 m) deep. The Providence Mountains limit this volcanic area on the east, but northward other less known centers exist.

CLIMATIC CHARACTERISTICS.

Southern California possesses a variety of climates, but throughout the larger part of it aridity and high temperature are the dominant features. There are few, if any, absolutely frostless localities, but there are many where only light frosts ever occur, and which may be quite untouched for several successive years. At altitudes below 1,500 ft (457 m) the midwinter temperature rarely falls below 25° F. (−4° C.), and the same altitude marks the ordinary limit of even light snowfalls.

But ascending to higher altitudes a different climate and a cooler temperature is soon reached. Thus at San Bernardino

[9] This peculiar coloration gave the Calico Mountains their prosaic name, in reference to their variegated tints.

(1,075[ft], 328[m]) in the five years 1895–9 the highest point reached by the thermometer was 110° F. (43° C.) and the lowest 23° F. (−5° C.).[10] At Little Bear Valley, 5,150[ft] (1,569[m]), in the adjacent mountains, distant about 12 miles (20[km]) in an air line, the extremes during the same years were 93° and −2° F. (34 and −19 C.).[10a] That is, a temperature was reached in summer in the valley 17° above that of the mountain, while the winter temperature lacked 21° of falling so low. At Big Bear Valley, 6,500[ft] (1,981[m]) a temperature of −14° F. (−25.5° C.) has been observed,[11] frosts occur in midsummer, and ice sometimes forms on an August night. No observations have been made at greater altitudes, but it is evident that at 10,000 or 12,000[ft] (3,000–3,600[m]) very low temperatures must be reached. These lofty summits are white in the winter months, and on their northern slopes the snow fields often linger late into summer. After a winter of unusual accumulations some shrunken remains may even persist into a second season.[12] Even at altitudes as low as 6,000–7,000[ft] (1,830–2,130[m]) there are sheltered cañons where snow banks yet linger at midsummer.

Contrary to common opinion, recorded observations establish the fact that lower temperatures are reached at stations in the desert region than at places having the same altitude on the seaward side of the mountains.[13] A great difference is shown also at the other extremity of the scale. The highest temperatures recorded on the coast are 85°–100° F. (30–38° C.); further back from the sea 100°–112° F. (38–44° C.) is reached; but at stations in the deserts records of 115°–128° F. (46–53° C.) have been made.[14]

The annual precipitation is very unequal in amount, not only in the different regions, but in the same region in different years. As an example of yearly variability the rainfall at Los Angeles

[10] From the Records of Dr. A. K. Johnson.

[10a] Records of Arrowhead Reservoir Co. [11] Records of the Bear Valley Co.

[12] Mean annual snowfall at Little Bear Valley 1895–9, 73[in] (1,854[mm]); greatest single snowfall, 39[in] (990[mm]). Records of Arrowhead Reservoir Co.

[13] At Victor, in the Mojave Desert, altitude 2,713[ft] (828[m]) killing frosts occur in August.

[14] At Mammoth Tank, July, 1887, 128° F.; July, 1884, 126° F.

of 32.25 in (819 mm) in 1869 may be compared with that of 4.83 in (122 mm) in 1898. In the desert region the rainfall is always very small, and in average seasons is greatly exceeded by that of the cismontane region, but years of extreme drought have occurred in which the difference was less marked.

The appended table exhibits the normal amount of precipitation at places whose records extend over a period of more than fifteen years. The average for the three intramontane stations is 14.95 in (380 mm), or about five times that of the desert station.

NORMAL PRECIPITATION.

Stations	Altitude		Years of Record	Monthly Precipitation				Yearly Precipitation	
				Least		Greatest			
	Feet	Meters		In.	Mm.	In.	Mm.	In.	Mm.
Los Angeles	270	84.1	21	T	T	4.0	102	18.1	460
San Diego	12	3.6	42	0.1	2.5	2.1	53	9.8	249
San Bernardino	1,075	327.6	29	0.3	7.6	3.6	91	17.0	432
Yuma	140	42.7	16	T	T	0.6	15	3.2	77

Nearly as great a disparity exists between the rainfall of the intramontane and the Nevadan regions, but data from the latter are few and not easily obtained. A partial means of comparison is afforded by the following table. The seasons are from July to June. The distance of the two stations in an air-line is about 12 miles (20 km); the difference of altitude is 4,075 ft (1,242 m).

PRECIPITATION FOR SIX SEASONS, 1893–94 TO 1898–99.

Stations	Altitude		Precipitation					
			Greatest		Least		Mean	
	Feet	Meters	In.	Mm.	In.	Mm.	In.	Mm.
San Bernardino[14]	1,075	328	20.98	533	7.49	190	11.61	295
Little Bear Valley[15]	5,150	1,570	60.61	1,542	19.79	502	33.08	840

The rainfall at the mountain station is nearly three times

[14] Dr. A. K. Johnson's record. [15] Arrowhead Reservoir Co.'s record.

that of the subjacent valley. The seasons of greatest and least rainfall were synchronous.

But for the purposes of the present inquiry the extreme of moisture and drought to which plant life is exposed is of as great importance as the average amount of rainfall; and the distribution in time of this amount is a factor of equal value. Again it will be found that in these respects the desert vegetation is at a disadvantage. Throughout the deserts total yearly rainfalls of 1.5 to 4 in (38–101 mm) are the rule, and at some stations a whole year may pass with absolutely no measurable precipitation. But this small amount is so evenly distributed through the year as to produce much less effect, certainly for annual plants, than if it were concentrated in a few months. The table below shows the normal distribution of rainfall throughout the year at two desert stations, compared with that at two stations on the coast.

NORMAL MONTHLY PRECIPITATION IN INCHES.

Stations	Years	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Keeler	8	0.2	0.4	0.2	0.3	0.4	0.2	0.1	0.2	0.3	0.3	0.4	0.4	3.3
Yuma	16	0.4	0.6	0.2	0.1	T	T	0.1	0.4	0.1	0.3	0.3	0.6	3.2
San Diego	42	1.6	2.1	1.0	1.0	0.3	0.1	0.1	0.1	0.1	0.3	1.0	2.1	9.8
Los Angeles	21	3.9	4.0	2.2	1.3	0.3	0.1	T	0.1	T	0.7	1.6	3.7	18.1

It here appears that the scanty rainfall of the desert stations is quite evenly distributed through the whole year, while at San Diego 9.1 inches out of the total 9.8 inches, and at Los Angeles 17 inches out of 18.1 inches fell during the growing season between November and May. That is, over 95 per cent. of the total rainfall at these places comes at a time when, owing to a lower temperature and a more declined sun, it is not subject to rapid evaporation, and avails most for the growth of vegetation. On the other hand almost all the desert rainfall may be regarded as ineffective by reason of its equal distribution.

It must be remembered, however, that all our recorded observations were made at stations in the open deserts, whereas had they been made in the cañons of the circumscribing mountains, somewhat more favorable results would have been obtained.

The rainclouds hug the mountains, and in winter one often may pass from the bright sunshine of the desert valleys through mist and drizzle to heavy showers by ascending for a few miles some cañon leading up the mountains. Hence it is in the cañons that the botanist learns to expect the most abundant and varied vegetation.

The desert mountains are also the scenes in midsummer of "cloud-bursts," or violent thunderstorms. These discharge in a short period and over a limited area a great quantity of water, and for a few hours the parched cañons are filled with rushing torrents. I have found a measurement of but one of these "cloud-bursts," and that only partial. At Campo on a day in August, 1891, there fell in such a storm 16 in (406 mm) of rain, before the gauge was washed away, preventing a complete measurement.

On the seacoast the aridity of the atmosphere is modified by frequent fogs and damp air-currents from the sea; and these ameliorating influences extend their benefits, in a less degree, inland, but do not pass beyond the mountains to modify the dryness of the desert air, while the strong winds almost constantly blowing there, produce a further desiccating effect.

PHYTOGEOGRAPHICAL AREAS.

It will readily be understood, from the preceding account, that the region under consideration consists of three divisions, differing from one another in both topography and climate. Consequently each of these will be found to possess a distinct and characteristic flora, and to constitute a separate life area.

In its relation to the biological divisions proposed by Dr. Merriam[16] the entire territory may be regarded as a part of the Sonoran province, in the midst of which arise two isolated peaks belonging to the Boreal province. A scanty Arctic flora occupies the summits of these peaks, and beneath it a diligent study can disentangle the Hudsonian and Canadian zones. This has been worked out very carefully and thoroughly by Mr. H. M. Hall,[17]

[16] MERRIAM, J. HART, N. Am. Fauna 3:20, map 5; National Geo. Mag. 6:229; Yearbook U. S. Dept. Agr. 1897:203.

[17] HALL, HARVEY M., A botanical survey of San Jacinto Mountain. Univ. of Cal. Pub. Bot. 1:1–144.

for San Jacinto, one of these mountains; the other, San Bernardino, yet awaits such detailed study.

But as might be expected from the position of the mountain chain, narrow and between two hot and arid districts, the zonal differentiation is not here carried out to the extent, or with the distinctness, that is exhibited in mountains more favorably situated, and of greater area. Indeed, the commingling of the Hudsonian and Canadian with the Neutral (*Pinus ponderosa*) belt is a marked feature of these mountains.

While, therefore, in a detailed study the separation of these zones may be preserved advantageously, it is more convenient for the purposes of a general view to unite the whole pine belt, which I propose to do under the name of the Nevadan area.

Above it the Arctic flora is feebly represented; and by it the remaining territory is divided into two life-areas. The Desert area comprises the deserts north and east of the Nevadan Range; the district between that range and the sea may be designated as the Cismontane area.[18] It remains to consider the character and limits of these several divisions, and of their subdivisions.

THE ARCTIC-ALPINE ZONE.

As has been stated already this zone is represented only on the summits of the two highest mountains, Grayback and San Jacinto. And it is but the scanty vestiges of an Arctic flora that lingers on these lofty summits, much scantier than their altitudes would justify one in expecting, even taking into consideration that this is the southern known limit of the Arctic flora on the North American continent. The summit of Grayback is flat and consists of porous decomposed granite, unfavorable to the growth of plants. San Jacinto is more fortunate, having on its precipitous northern face some steep, shaded cañons, preserving perpetual snows. But for all that, it does not exceed in species its less favored neighbor. A single species, *Ranunculus Eschscholtzii*, has been found on both peaks, *Arenaria hirta verna* and *Antennaria alpina* have been collected on Grayback, while from San Jacinto *Carex Preslii* and *Oxyria digyna*

[18] This has been designated usually as the Intramontane area, but the present term seems preferable.

have been added to the short list. Further explorations may be expected to increase it, but not greatly.

THE NEVADAN AREA.

The lower limit of this area coincides with that of *Pinus ponderosa*. On cismontane slopes this is seldom below 5,000ft (1,524m) altitude; but on the opposite side the influences of the desert force it up to 6,000ft (1,828m), and even to 7,000ft (2,133m) above sea level. This region contains the only real forests in the entire territory, and while these are far inferior to those in the damper and cooler parts of the Pacific Coast, they are by no means insignificant, either in extent, or in the size and variety of the trees which compose them.

As already stated the zones which I have included in this area are much confused. Perhaps the best marked is the Hudsonian, which we may consider as indicated by the presence of *Pinus flexilis*. This is known to occur on Grayback, San Jacinto, and Santa Rosa peaks, and it should be found on one or two other high summits. As a zonal index its proper limit would be between 9,000 or 10,000 to 12,000ft (2,750–3,650m). But under favorable conditions it descends 1,000–2,000ft (300–600m) lower into the Canadian, and in at least one instance an isolated Hudsonian "island" occurs at 6,500ft (1980m), well down in the Neutral or Transition zone.[19]

The Canadian zone, which may be taken as indicated by *Pinus Murrayana*, is even less definitely marked. This pine is not uncommon in places as low as 6,500ft (1,980m), but it is better developed in moist valleys 1,000–2,000ft (300–600m) higher, and becomes more abundant as one ascends, until it mingles with the limber pine of the superior zone.

But the most important zone is the Neutral, or Transition; and it is the only one represented in the greater part of the Nevadan area. The principal tree throughout this zone is *Pinus ponderosa*. Its lower limits have been specified, and its upper limit may be placed at 8,500ft (2,590m), or occasionally, and under favoring conditions 500–1,000ft (150–300m) higher.

[19] For an account of this see "The Flora of Snow Cañon, California," by the writer, in Plant World 4: 227.

With this species is intermixed a considerable proportion of *Abies concolor*, *Libocedrus decurrens*, *Pinus Lambertiana* and some *P. ponderosa Jeffreyi*, without zonal differentiation, except that the Abies is more abundant and of greater size toward the upper limit, at 7,500–8,000 ft altitude (2,286–2,438 m).

On each slope of the mountain there is, beneath the Pine or Neutral zone, an intermediate, or true Transitional zone. The one differs entirely from the other, each possessing plants peculiar to itself and also representatives of the superior and the inferior zones. On the desert side this zone is nearly crowded out, and is present only in a narrow strip, between 6,500 and 7,500 ft (1,980–2,286 m) altitude, along the northern slope of the San Bernardino Mountains, and reaching from Bear Valley some fifteen miles towards Cajon Pass. It is indicated by an abundant growth of *Juniperus Californicus* and *Cercocarpus ledifolius*. It is much intruded upon by the plants of the zones above and below it, and within its limits may be seen in juxtaposition such incongruous species as *Pinus ponderosa* and *P. monophylla*, *Abies concolor* and *Yucca brevifolia*.

Of this transitional character, also, is the belt of *Pseudotsuga macrocarpa* and *Pinus Coulteri*, extending along the cismontane flank of the Nevadan Range, at 3,000–4,500 ft (915–1,370 m) altitude. The former is more abundant at the northern part of the belt, and the latter at the south, where it occupies a position similar to that of the closely allied *P. Sabiana* in the foothills of central California. To the north *Pinus Coulteri* is commoner on the lower ridges within the *P. ponderosa* zone.

The following table shows those genera which, in our territory, are found only in the Nevadan area.[20] Genera which are abundant and widely distributed are in SMALL CAPITALS; those local and rare in *italic*.

[20] In this, and in subsequent tables of regional distribution those genera are omitted which are represented by endemic species only. Want of space prevents an extension of this investigation to the species of such genera as have representatives in more than one area, but its extension to these would be found to reinforce the conclusions reached. In determining the sources, or geographical affinities, of the elements composing the floras of the different areas, regard is had, not to the distribution of the genus as a whole, but of the particular species under consideration.

GENERA FOUND ONLY IN THE NEVADAN AREA.

Exclusively Nevadan		Boreal	
LIBOCEDRUS	Heracleum	Athyrium	Pterospora
Danthonia	*Pyrola*	*Woodsia*	Geum
Hemicarpha	*Chimaphila*	CYSTOPTERIS	HYPERICUM
VERATRUM	SARCODES	*Cryptogramma*	Circæa
Iris	Rhododendron	ABIES	Hippurus
Corallorhiza	*Brianthus*	Alopecurus	Myriophyllum
CASTANOPSIS	*Cycladenia*	Glyceria	Gentiana
SPRAGUEA	*Boschniakia*	Puccinella	*Polemonium*
Lewisia	KELLOGGIA	*Trisetum*	Lappula
Heuchera	Hemizonella	Luzula	Taraxacum
Philadelphus	Hulsea	Smilacina	Crepis
Heterogaura	*Raillardella*	Actæa	Hymenopappus
Sphænosciadium		BARBAREA	Arnica

In the first two columns are placed those genera which, as to the species by which they are here represented, belong exclusively to the flora of the Sierra Nevada; in the last two those which have a more or less wide distribution throughout the whole Boreal province. But it is to be noted that every genus, without exception, has for its representatives in our flora the identical species which are found in the more northern parts of the Sierra Nevada. Moreover, with the exception of eight of the Nevadan genera and three of those of wider distribution,[21] all belong in the so-called Neutral or Transition zone.

From a consideration of this table it is evident that the flora of these southern mountains coincides with that of the general Sierra Nevada, of which it is physiographically a part. And so far as its position in the phytogeography of North America is indicated by distinctive genera, the Transition zone is preponderately Boreal rather than Sonoran.

THE DESERT AREA.

The Desert area consists of two very distinct subareas: the Mojave subarea, which includes all the country to the north and east of the San Bernardino and Chuckawalla Mountains; and the Colorado subarea, which consists of the great desert valley between the Chuckawalla Mountains and the southern prolonga-

[21] Namely: *Castanopsis, Philadelphus, Pyrola, Chimaphila, Bryanthus, Cycladenia, Boschniakia, Raillardella, Athyrium, Woodsia, Cryptogramma.*

tion of the main range. These are locally known as the Mojave and the Colorado Deserts.[22] These two subareas have many plants which are common to both, but each possesses also a distinctive flora. These characteristics, so far as they relate to genera, are exhibited in the subjoined table.

GENERA PECULIAR TO THE DESERT AREA.

Colorado Subarea	Mojave Subarea	Both Subareas
Northeastern Element	Northeastern Element	Northeastern Element
Astephanus	*Actinella*	Anisocoma
	Amsonia	Grayia
Southeastern Element	Atrichoseris	Piptocalyx
	*Bouteloua	*Tricardia*
Wedelia	Cleomella	
*Argythamnia	*Eurotia	Southeastern Element
Ayenia	*Forestiera*	
*Beloperone	Glossopetalon	Acamptopappus
Boerhaavia	Glyptopleura	Achyronichia
Calliandra	Kochia	Baileya
*Cercidium	Lygodesmia	Bernardia
Chloris	Monoptilon	Cladothrix
Condalia	Phellopterus	Hilaria
Dicoria	Pursh ia	*Krameria
*Fagonia	Stanleya	*Larrea
Fouquiera	*Salazaria	Mohavia
*Hibiscus	*Syntrichopappus	Nolina
*Horsfordia		Thamnosma
*Hoffmanseggia		Trichoptilium
*Hofmeisteria		
*Hyptis	Southeastern Element	Indefinite
*Leptochloa		
Martynia	*Canotia*	Calycoseris
*Olneya	Coleogyne	Chylisma
*Parkinsonia	*Fallugia*	*Dalea
Pectis	*Psilactis*	*Ephedra
*Peucephyllum		Petalonyx
*Palafoxia		Psathyrotes
*Porophyllum		Sphaeralcea
Sesbania		
*Triodia		
Tribulus		
Trixis		
*Washingtonia		

It appears by this table that the desert genera fall into three nearly equal groups: namely, those which are found only in one or the other of the two subareas, and those which occur in both

[22] The region bordering the Colorado River is too little known to permit exact statements regarding it. There are reasons for believing that the Colorado subarea should include the interval between the river and the eastern slope of the Providence Mountains.

of them. I have separated the genera of each group into two sections; a northeastern section for those whose extensions are into Nevada, Utah, and the Great Basin life-area; and a southeastern section to include those whose extensions of range are into Arizona, and towards or into northern Mexico. There remains a group in the third column whose affinities cannot be stated definitely, mostly because represented by more than one species which have diverse ranges. Genera which are represented by species which also extend into the peninsula of Lower California are distinguished by an asterisk. Washingtonia has its only extension in that region.

It is to be noted that Astephanus, the single northeastern genus peculiar to the Colorado subarea, is known from a single collection. All the others are southeastern, and all but ten extend into Lower California. On the other hand Canotia and Fallugia, two of the southeastern plants of the Mojave subarea, are found only in the Providence Mountains, which may belong to the Colorado subarea. Only four of the peculiar Mojavan plants have been reported from Lower California.

Like geographical affinities are exhibited by the different species of certain genera which are differently represented in each subarea. A longer list than the following might be compiled, but these examples must suffice.

DISTRIBUTION OF CERTAIN DESERT SPECIES.

Colorado Subarea	Mojave Subarea
Agave *deserti	Agave utahensis
Aster Orcuttii	Aster tortifolius
Cassia *Covesii	Cassia armata
Coldenia canescens	Coldenia Nuttallii
—— *Palmeri	
Dalea *Emoryi	Dalea Fremonti
—— Parryi	—— polydenia
—— *Schottii	
—— *spinosa	
Gilia *bella	Gilia dichotoma
—— *Schottii	—— Matthewsii
—— *tenuifolia	—— setosissima
Lupinus arizonicus	Lupinus brevicaulis
Pentstemon ambiguus	Pentstemon glaucus
Phacelia micrantha	Phacelia Ivesiana
Psathyrotes *ramosissima	Psathyrotes annua

All the species in the Colorado column have southeastern affinities; all those in the Mojave column have northeastern affinities. In the former, ten out of sixteen extend into Lower California; in the latter, none.

The distribution of the desert flora, and fauna as well, is not known, as yet, with sufficient exactness to permit positive statements. But facts already accumulated indicate that in the Colorado subarea the Lower Sonoran flora, which extends over the entire desert area, is very slightly modified by any other. The Mojave subarea, on the contrary, shows a marked influence from the Great Basin life-area. The limit to which this extends appears to be defined by the Chuckawalla Mountains.

While it is true that, within our territory, the general elevation of the Mojave Desert considerably exceeds that of the Colorado Desert, a difference having an undoubted modifying effect on their floras, yet the precipitation, the temperature, and other conditions of the two subareas are very similar. And the conclusions at which we have arrived would be strengthened were the investigation to be extended so far beyond our limits as to include the depression of Death Valley. Hence it may be inferred that the difference in the character of the two floras is only in part due to climatic causes, but is largely influenced by the topography of the region. In the one case a current of migration was able to pass up, encountering no physical barriers, from Arizona and Lower California into the Colorado Desert; in the other a current from eastern Utah and Nevada would meet no considerable obstacle until it reached the San Bernardino Range and its continuation.

The distinctness of the two subareas is further evident from a consideration of the zonal distribution of their respective floras. Much remains to be learned before these zones can be delimited accurately and finally; but sufficient data are at hand to permit their general disposition to be outlined, leaving the details for completer knowledge.

The Larrea belt, which is considered as indicating the limits of the Lower Sonoran, is present in both deserts. But however useful this shrub may be as the biological index of larger

divisions, it is of less importance in the study of smaller areas. Within these narrower limits it is probable that more than one subzone may be traced, but much fieldwork must be done before this can be accomplished satisfactorily. There are indications, however, in the Colorado Desert of a subzone below the Larrea, whose limits appear to be traceable by the growth of *Atriplex polycarpa*. But for the present the Larrea zone may be taken as a whole, and considered as extending over all parts of the two deserts below 3,000 ft altitude (915 m).

Above the Larrea, the zones of the two deserts, although analogous, are indicated by entirely different plants. In the Mojave Desert the first zone above is that of *Yucca brevifolia*. This belongs properly between 3,000 and 4,000 ft (915–1,220 m) altitude; occasionally, however, it descends 500 ft (150 m) lower, or again carries its characteristic species as high as 7,000 ft (2,133 m). In its normal limits *Juniperus californica* is mingled with the Yucca, but does not accompany it far above them. The principal belt of this zone, beginning at the upper end of Antelope Valley, follows the base of the San Bernardino Range to Warrens Wells, and thence, along the Chuckawalla Mountains, at least to Virginia Dale. A less important belt extends from Daggett to Pilot Knob.

Above the first named Yucca belt is the Piñon zone, marked by the presence of *Pinus monophylla*, having an altitudinal breadth between 4,000 and 6,000 ft (1,220–1,830 m). It also begins in Antelope Valley, and extends, but with considerable interruptions, from Gormans Station to and beyond Warrens Wells, and possibly even to Virginia Dale.

In the upper end of Antelope Valley the orographical confusion which there exists has given rise to a curious phytogeographical anomaly. Here *Pinus Sabiniana*, *Quercus Douglasii*, and *Q. Wislizeni*, trees characteristic of the western slope of the Sierra Nevada throughout central California, coming through Tejon Pass, find themselves on the *eastern* slope of that range, and the unusual sight is presented of desert foothills clothed with an almost unmixed growth of scrub-oaks. Here, too, are found *Aesculus californica*, *Balsamorhiza deltoidea*, *Gilia tricolor*, *Layia*

heterotricha and *Collinsia Torreyi*, which have entered through the same gate to share the anomalous position of the oaks.

In the Colorado Desert the Yucca zone is replaced by a well-defined zone of *Agave deserti*, which, in an almost continuous belt between the altitudes of 2,500 and 4,000 ft (760–1,220 m), stretches along the desert slopes of the mountains from San Jacinto Mountain to and beyond the Mexican boundary. The plants of that zone, with inconsiderable exceptions, are quite distinct from those of the corresponding Yucca zone of the Mojave Desert, although it has the same altitudinal limits, and other physiographical conditions.

Above this Agave zone there is a little known Piñon zone. It begins southeast of San Jacinto and extends to El Toro Mountain, above Toros, its upper limit being about 5,000 ft (1,525 m) above sea level. Possibly, in the little-explored mountains between El Toro and the Mexican line, other traces of this zone may connect it with the extensive nut-pine forests of the peninsula. At its upper end this belt is mainly composed of *Pinos monophylla*, while on El Toro, *P. Parryana* has supplanted it.[23]

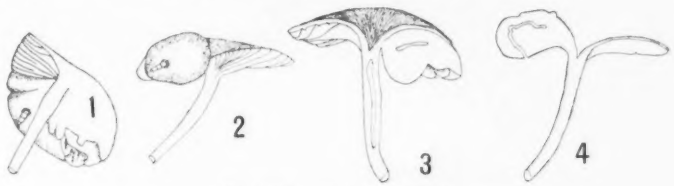
[23] These two species appear either to coalesce, or to hybridize, in this belt. Specimens may be found in which there are, on the same twig, sheaths containing two, three, or four leaves.

[*To be concluded.*]

BRIEFER ARTICLES.

A GALL UPON A MUSHROOM.

WHILE collecting fungi in one of the gorges in the neighborhood of Ithaca, September 12, 1902, I found two specimens of the common *Omphalia campanella* affected by a gall insect. Every fungus collector is familiar enough with the destruction of his choicest mushrooms by insect larvae, but in every case that has been recorded, so far as I can determine, the effect of insect attacks has been exclusively destructive. However completely the fungus may be riddled by larvae, there is ordinarily no growth-response whatever on the part of the plant.



Omphalia campanella Batch.

FIG. 1. — Half of pileus affected by gall insect, showing normal gills and gall viewed from below.

FIG. 2. — Same viewed from the side.

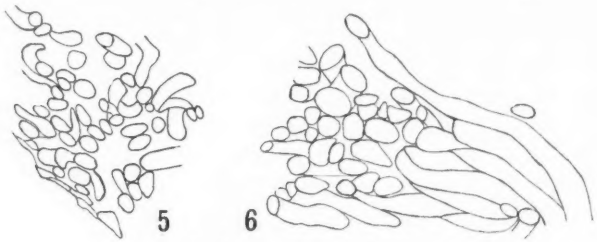
FIG. 3. — Same showing the appearance of the vertical section.

FIG. 4. — Vertical section showing the path of the larva within the gall.

Here we have a very different condition of affairs, as the accompanying figures will show. The normal pileus of *O. campanella* is very thin, in fact less than 1^{mm} in thickness, and with gills attached the entire structure is inside 3^{mm}, as a rule. Here, in contrast, we have a white mass, homogeneous in section, about 8^{mm} in radial diameter, 6^{mm} in thickness, and some $12–15^{mm}$ in length. Around the ends of the gall, where it adjoins the normal tissue, the even under-surface is broken, as represented in *figs. 1* and *3*, the folds and wrinkles representing gills whose original nature becomes more evident as they approach the normal tissue. The effect upon the upper surface is shown by *fig. 2*. In this the gall causes a marked enlargement, deforming that half of the pileus. The two galls were much alike

in general appearance. There were five larvae in the two together. One of these is sketched in the figures as it was fixed and remained in the opening of its hole. The larvae were determined by Mr. W. A. Riley, of the Department of Entomology of Cornell University, as dipterous larvae of family Mycetophilidae. Further identification was impossible, and since an attempt to cultivate them resulted in the loss of one and the larger part of one gall, the remainder were killed and fixed for study.

To see what changes had occurred in the tissues, portions of one gall were imbedded in paraffin and sectioned for comparison with



Omphalia campanella Batch

FIG. 5.—Camera lucida sketch of normal hyphae.
FIG. 6.—Camera lucida sketch of hyphae from the gall.

sections of a normal Omphalia gathered from the same place. Camera lucida sketches of portions of these sections look at first very much alike. The intercellular spaces are reduced somewhat and the hyphae appear swollen. Measurement of the diameters of a large number of hyphae gives a marked contrast. The average of forty measurements of diameters of cells in the same microscope field was, in the normal tissue, about 7 μ; in the gall the average was between 9 and 10 μ (*figs. 5*, and *6*). These figures show the stimulating effect of the attack of the gall insect. It has in this case not only produced a relatively very large growth, but has caused a very noticeable increase in the average size of the hyphae (nearly one-third). Hyphae of normal size occur among the swollen threads of the gall, and larger ones are found in the normal tissue, but the averages are strikingly different. A stimulus which is to produce so marked an effect, both in obliterating the lamellae completely and increasing the size of the hyphae themselves, must be applied to the mushroom before gill formation has taken place, else its effect would be destructive, not constructive. It would seem, then, that in these cases the eggs must have been laid very early, so that the abnor-

mal growth kept pace with the larvae, which are comparatively large for so small a mushroom. The hole traced out in *fig. 4* appears to represent the habit of the larva. It has been suggested that most gall insects produce hollow or chambered abnormal growths, and that this may not be a form which habitually produces galls. It is of course possible that the eggs were laid very early and that this stimulus produced a gall, whereas had they been laid later the mushroom would have been destroyed in the ordinary way. The argument that this is a true gall insect would be the size of the gall, and of the larva producing it (5–6^{mm} at least). Larvae as large as these could not work in the ordinary Omphalia pileus because the flesh is too thin and would not offer sufficient food and protection, which is always sought by the insect in laying eggs. It is at least interesting to find such a gall in a group of plants where such a growth has not been reported in our literature. This note, perhaps will bring similar cases to light.—CHARLES THOM, *Cornell University, Ithaca, N. Y.*

SELECTED NOTES. II.—LIVERWORTS.

DUMORTIERA.—Although the genus Dumortiera has as a whole become greatly reduced in the structure of its gametophyte from the typical Marchantia form, and has, generally, hardly a trace left of the complex chambers and nutritive outgrowths characteristic of the group, there are certain species which show, normally or occasionally, enough resemblance to the typical form to leave no doubt that its simplicity is secondary, acquired through retrogressive development from more complex members of the Marchantiaceae. Of the several species of Dumortiera there is only one in which traces of dorsal chambers have been described. This is *D. irrigua* L., which was studied by Leitgeb[1] from herbarium material only. At the growing point on the upper surface he finds and figures quite distinct chambers, without, however, a very definite mouth opening. The upper covering of the chambers becomes broken and disappears more and more on the older part of the thallus, until finally only the basal parts of the chamber walls are left as reticulations on the surface. Leitgeb also mentions "kürzeren oder längeren Haarpapillen" which occasionally arise from the surface of the thallus and represent the cell rows which fill the air-chambers of Marchantia. Campbell (*Mosses and Ferns*) finds no trace of any such complexities on the thallus of *D. trichocephala* from the

[1] Untersuchungen über die Lebermoose, Heft 6, 1881.

Hawaiian Islands.[2] He says: "No indication of lacunae can be seen either near the apex or farther back, the whole thallus being composed of a perfectly continuous tissue without any intercellular spaces." Schiffner[3] describes two species of Dumortiera from Java, *D. trichocephala* and *D. velutina*. Of the first he says: "Frons oberseits ohne oder nur mit zerstreuten Papillen übersät." In neither species does he mention the presence of any trace of air chambers or reticulations. In the possession of numerous papillae on the upper surface *D. velutina* shows itself to be less reduced than *D. trichocephala*.

Z. Kamerling[4] gives a figure of *D. hirsuta* which shows the upper surface thickly covered with unicellular papillae. He refers to Leitgeb's work on *D. irrigua*, but does not mention finding any trace of chambers in *D. hirsuta*. My own observations on the last-mentioned species, which grows rather abundantly in two situations around Chapel Hill, bring out the presence in some cases of air chambers in the young parts of the thallus, which closely resemble those in *D. irrigua*.

Our species, like others of the genus, grows in wet, springy places where the water is constantly trickling through, and it evidently requires more moisture than any other members of the Marchantiaceae (with the exception of Riccia) that occur in this region. Z. Kamerling,[5] in his classification of the Marchantiaceae according to biological types, has considered Dumortiera with good reason as typically hygrophilous, and there seems little doubt that the loss of its air chambers is due to its semi-aquatic life.

The spot where Dumortiera is most abundant here is a gentle rocky slope on the north side of a well-wooded hill, where spring water is constantly oozing out and keeping the thalli saturated. Plants from this place show no air chambers. The other spot where Dumortiera has been found is under a series of overhanging rocks that have been hollowed out so as to form caves 8 to 12 ft deep. At the base of these caves the liverwort grows on the damp porous sand, where the water never seems to accumulate so as to cover the plants. Specimens from this situation can be plainly seen with the naked eye to be reticulated over the entire surface, as shown in *fig. 1*, which is from a

[2] See also CAMPBELL, The systematic position of the genus Monoclea. BOT. GAZ. 25: 272–274. 1898.

[3] Die Hepaticae der Flora von Buitenzorg. Leiden. 1900.

[4] Zur Biologie und Physiologie von Marchanticeen. Pp. 73, *pls. 4*. München, 1897.

[5] *Op. cit.* p. 38.

photograph. From sections made through the growing point it could be seen that in the younger parts the air chambers were about as perfect as in Marchantia. Such a chamber is shown in *fig. 2*. It will be noticed that the pore at the top is not so definite as in typical cases, but in every other way the chamber is perfect. There are several cells projecting from the floor, which contain chromatophores and are no doubt the homologues of the filaments filling the chambers of Marchantia, as remarked by Leitgeb. These papillae are not at all abundant, but are scattered here and there, and often persist in the older parts. They were never found to form chains of cells, as in more complex thalli. As they become further and further

FIG. 1.—*Dumortiera hirsuta*. Two thalli of natural size; from a photograph.

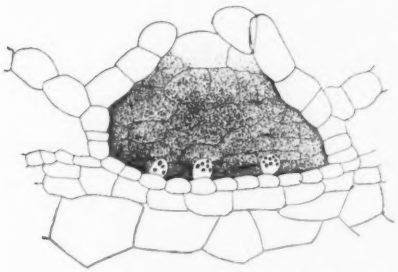


FIG. 2.—The same. Section through an air chamber. ×246.

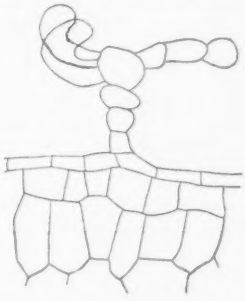


FIG. 3.—The same. Wall of chamber an older part with a few cover cells still attached. × 246.

removed from the growing point, the air chambers become less perfect, the roof cells become torn apart, and many are thrown off, until only a few remain around the upper edge of the wall cells (*fig. 3*). Finally, on the older parts, only the basal cells of the partition are left to form the reticulations seen in *fig. 1*.

It will be seen that we have in *D. hirsuta* chambers and papillae

which almost exactly resemble those found by Leitgeb in *D. irrigua*. They show beyond a doubt that the thallus of Dumortiera has been derived from more complex forms. It seems probable that the comparative darkness of the caves where the plants are found was the factor that induced the formation of the papillae, and that the absence of surface water was favorable to the development of the air chambers.

The "delicate appressed pubescence" mentioned by Underwood (Gray's *Manual of Botany*) as sometimes present on the upper surface of *D. hirsuta* is no doubt the remnants of the air chambers here described.

In his work on the mycorhiza of the Marchantiaceae N. Golenkin[6] could find no trace of fungus in Dumortiera, although he demonstrated it in Preissia, Marchantia sp., Fegatella, and others. I have looked carefully for mycorhiza in Dumortiera, but in no case was any found in the thallus cells. Fungus threads were often seen running up inside the rhizoids, but they were never traced into the living tissue. There is no difficulty in finding abundant mycorhiza in Fegatella.

BLASIA PUSILLA L.—The symbiotic relation of Blasia and Nostoc has often been noted, and Leitgeb (*op. cit.* Heft 1) has given a very good description of the structure and origin of the peculiar chambers of the Blasia thallus in which the Nostoc lives. He failed, however, to get a preparation showing a section of a fully developed chamber with contents, and does not give a drawing that shows the contents. By pressing out the Nostoc he found that the colony was penetrated by clear cells, which he correctly deduces to be branches of the Blasia thallus that have arisen from the slime-secreting hair that was present in the young stages. As the origin of the branched cells ramifying through the Nostoc is so peculiar, I give a drawing (*fig. 4*) that illustrates this point in a mature Nostoc chamber. There grows up from the floor of the chamber a tree-like structure with a single trunk, and from the repeated ramifications of this tree the whole colony becomes interwoven with cells which doubtless serve to abstract nourishment from the algae. This whole ramifying structure has in all probability come, as Leitgeb thought, from the subsequent growth of the slime-secreting cell shown in *fig. 5, s*.

This cell, in the young stage shown, projects upward into the "Blattohr," as Leitgeb calls it, while at the opening at the base on one side the Nostoc enters. This opening is soon closed, and as the cavity

[6] Die Mycorhizaähnlichen Bildungen der Marchantiaceen. Flora **90**: 209–220, *p. 11*. 1902.

grows larger and the Nostoc multiplies, the tree-like upgrowth is produced. In other cases of such symbiotic relationships, as Anthoceros, there are, likewise, cells growing in from the host plant; but in all such cases, so far as I know, these outgrowths originate, not from a common base, but separately and at many points. The striking and beautiful arrangement in Blasia seems to be confined to it alone.

SPHAEROCARPUS TERRESTRIS Smith.—I have found this liverwort abundantly at Chapel Hill, N. C., Selma, N. C., and Florence, S. C. Active spermatozoids were obtained in April of this year from Chapel Hill plants, and it is probable that they are liberated during the greater

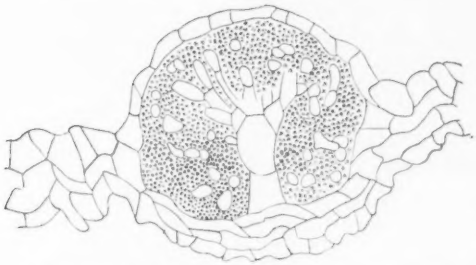


FIG. 4.—*Blasia pusilla*. Section of a large Nostoc chamber. × 166.

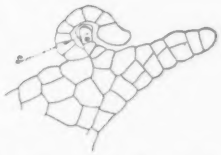


FIG. 5.—Section of a young chamber. × 250.

part of the growing season, as sporophytes of all ages can be found at almost any time.

It is the sterile cells of the sporangium, however, that I wish especially to mention. They are so peculiar in appearance and behavior as to deserve more attention than they seem to have received. These cells, though probably the homologues of the elaters of higher forms, do not bear the least resemblance to them. They are round, have clear cell walls, and contain a good number of bright green chlorophyll granules. These granules retain their bright color almost to the time of the ripening of the spore. They then fade slightly to a yellowish-green, but are still distinctly colored and not the least corroded when the spores are quite ripe. If a ripe black sporangium is crushed under the microscope, these green cells at once attract attention as being totally different from any other sterile cells in the sporangia of either liverworts or ferns. They no doubt carry on photosynthesis to the last moment.

An attempt was made to keep these sterile cells alive on wet filter

paper, in the hope that they might divide; but, although they remain green and intact for more than a week, a gradual fading set in and they finally died. Perhaps they would behave differently in nutrient solution, but I have not yet tried this. Leitgeb (*op. cit.*, Heft 4) also failed in his attempt to sprout these peculiar cells.

In conclusion I wish to express my hearty thanks to Professor Alexander W. Evans for the loan of valuable literature.— W. C. COKER, *University of North Carolina, Chapel Hill.*

CURRENT LITERATURE.

BOOK REVIEWS.

An English class book of botany.

THE EXAMINATION SYSTEM of the higher educational institutions of Great Britain seems to dominate the writing of English text-books. Some such announcement as the following may be found in the preface of most of them: "This work is primarily intended to meet the requirements of students who are preparing for the Intermediate Scientific B.Sc. and Preliminary Scientific M.B. examination of the London University, or for the Advance Stage examination of the Board of Education. But students who intend sitting for other examinations, etc." This shows how heavy a responsibility rests upon the men who set these examinations, and if the subjects and methods they demand be not the ones best suited for training a student in botany—why, so much the worse for the student! The book before us[1] consists of four parts. Part 1 (280 pages) is a description of the structure of plant "types," including the sunflower, bean, elm, mare's-tail, water-lily, maize, yucca, pondweed, pine, selaginella, two ferns, polytrichum, pellia, fucus, ulothrix, spirogyra, vaucheria, haematococcus, agaricus, pythium, mucor, eurotium, yeast, bacteria, physcia; part 2 (130 pages) is concerned with special morphology and classication of angiosperms, under which are the flower and inflorescence, pollination, fruits and seeds, and about sixty pages giving the characters of the orders of angiosperms; part 3 (cut off with 65 pages) treats of the physiology of plants, while part 4 (16 pages) is a running glossary of descriptive terms. The text is reasonably accurate, though by no means flawless, and the book is certainly a compendium of information upon the topics which it treats. As the types are studied in the reverse order from their evolution, a philosophical presentation is practically impossible. Some tables of homologies are given, but the student must hold the facts by sheer strength of memory. The illustrations, "especially drawn for the work," are for the most part extremely crude and some are quite ludicrous. One can hardly imagine that the delineator of a section of a developing ovule (*fig. 84*, II) and of physcia (*fig. 150*) ever saw these structures. The book is not one that will be of service to American students, though it may be helpful to those who are obliged to sit for British examinations.—C. R. B.

Protoplasmic streaming.

A BRIEF ABSTRACT of his extensive work upon this subject was communicated to the Royal Society in February last by Dr. Ewart. Through the gen-

[1] MUDGE, G. P., and MASLEN, A. J., A class book of botany. 12mo, pp. xvi + 512. *figs. 228*. London: Edward Arnold. 1903. 7/6.

erous financial aid accorded by the Royal Society he has been enabled to publish the full treatise at the Clarendon Press.[2] Dr. Ewart's observations upon protoplasmic streaming have extended over eight years. The treatise shows complete familiarity with the somewhat extensive literature bearing directly upon this topic, and the prolonged study has enabled him to review much allied work, both physical and physiological. In these days, when hasty publication is too frequent, the author's mature consideration of his theme and the contemplation of it from many sides may be taken as an example worthy of imitation.

Some conclusions of this book have already been stated in the notice of the preliminary paper.[3] The study of streaming itself has brought Ewart to consider so many other aspects of cell physiology that it is not possible to summarize his conclusions without repeating the three or four pages in which he concisely does this. It must suffice to say that he discusses the influence of various external agents (including an extensive study of chemical, mechanical and etherial stimuli) on streaming; the relation between it and the other functions of the cell; the sources of energy; the influence of viscosity, and the ways in which this is modified by various agents; the analogies between streaming and molecular contraction; the transmission of stimuli and the rate of propagation; the existence of nerve fibrillae as claimed by Němec; the movements of chloroplasts; and finally the theories of streaming.

Typographically the book is issued in the same style as the classical textbooks of Sachs, DeBary, Pfeffer, and others, falling below their high standard only in the figures, which are reproduced from rather crude drawings. It would have been worth while to have a good draftsman put these into proper form. One dislikes to see unsightly illustrations in the midst of fine letter press.—C. R. B.

Biological philosophy.

SEEMINGLY almost all the fundamental problems of modern biology are at least touched upon in a curious work which has recently appeared from the hand of Krašan.[4] The book is of a decidedly philosophical nature and is designed as a sort of introduction to broad and deep scientific thinking. Its field is to some extent similar to that of Pearson's *Grammar of Science*, but the present work deals almost entirely with the facts of botany, and the method of treatment as well as the ideas expressed are quite different from those of the *Grammar*. In Krašan's felicitous illustrations and comparisons of things seemingly dissimilar (*e. g.*, of the animate with the inanimate, etc.), is found

[2] EWART, ALFRED J., On the physics and physiology of protoplasmic streaming in plants. Imp. 8vo. pp. viii + 131. *figs. 17*. Oxford: Clarendon Press. 1903.

[3] See BOT. GAZ. **36**: 71. 1903.

[4] KRAŠAN, F., Ansichten und Gespräche über die individuelle und specifische Gestaltung in der Natur. 8vo. pp. vii + 280. Leipzig: Wilhelm Engelmann. 1903. *M.* 6.

much to remind the reader of the Weissnichtwo Professor of Things in General; for students who have difficulty in seeing a number of sides to the same question the book will surely be an inspiration. Among the topics discussed are: the relation between material and form throughout nature; metamorphosis and substitution; the relation of species, variety, and race; phylogeny; paleobotany, etc.

The work has an almost medieval smack; after a few introductory pages it is written entirely in dialogue, which may make it tedious for him who is only after the kernel of the nut. There is no doubt, however, that the reader's interest is held by these curiously learned dialogues of Fritz, Hans, and the other students, albeit the ludicrous will occasionally arise to obscure the scientific.—B. E. LIVINGSTON.

MINOR NOTICES.

TREES, SHRUBS, and VINES[5] is a book designed especially for New Yorkers, and to them it may be useful. Though it professes to describe these plants in all the northeastern United States, this part is distinctly inferior and secondary. The greater part of the book is devoted to lists of "these three growths" and to "rambles" in Central Park, whose glories are fully exploited. To a brief description of native trees, shrubs, and vines 172 pages are devoted, and nearly half as much more to the foreign species grown in Central Park. The descriptions are too brief, lacking in contrasts, and often maddeningly comparative. Species of the same genus are often widely separated. The keys are worthless; *e. g.*, one of the chief distinctions is "widely distributed within territory" and "found only on frontier"—exactly the kind of information that one endeavoring to name an unknown tree is unlikely to possess. If the book sailed under true colors it would be more commendable; but judged according to its title it is far inferior to others of like purpose.—C. R. B.

NOTES FOR STUDENTS.

DUDE,[6] studying both fungi and higher plants, finds that the replacement of oxygen by purified hydrogen can be withstood by spores and seeds for a long time (in seeds fifteen to fifty days), but that their germination is much delayed. The vegetative tissues are injured irreparably after an hour or at most a few hours, the younger being most easily killed; yet meristematic tissues endure the hydrogen for three to five days. In all conditions a higher temperature accelerates the action.—C. R. B.

DR. B. LONGO[7] holds that the pollen tube is the only channel by which the embryo of Cucurbita can receive nutriment, because of the marked cutini-

[5] PARKHURST, H. E., Trees, shrubs, and vines of the northeastern United States. 12mo. pp. viii + 451: Illustrated. New York: Charles Scribner's Sons. 1903. $1.50.

[6] DUDE, MAX, Ueber den Einfluss des Sauerstoffsentzuges auf pflanzliche Organismen. Flora **92**: 205–252. 1903.

[7] LONGO, B., La nutrizione dell' embrione delle Cucurbita operata per mezzo del tubetto pollinico. Annali di Botanica **1**: 71–74. 1903.

zation of the cell walls in the chalazal region and of the nucellar epidermis, which is completed while yet the embryo is spherical. The only pervious point is at the tip of the nucellus, where the pollen tube forms a globular swelling and sends branches through the inner integument which extend into the outer. These branches collect the food from the integuments, which are in communication with the nutritive tissues by the vascular bundles, and through the pollen tube it travels to the embryo.—C. R. B.

VINES finds[8] that Buscalioni and Fermi had anticipated some of his studies upon proteolytic enzymes, having determined in 1898[9] by a different method entirely the rather extensive occurrence of such enzymes. In this second paper Vines summarizes their results and contributes further data. He shows that the antiseptic used may influence greatly the digestion (which explains Mendel and Underhill's results with papain); corrects Buscalioni and Fermi's determination that dahlia roots are proteolytically inactive; and finds an enzyme in *Crambe maritima* which belongs to the erepsin group of proteases.—C. R. B.

IN A SERIES of researches on the physiology and morphology of alcoholic ferments, Hansen[10] shows that in beer cultures Saccharomyces spores may develop into sporangia without vegetative division. They simply enlarge enormously and develop new spores in their interior. The maximum and minimum temperatures for growth as well as for sporulation in a number of species of Saccharomyces are given. Temperature does not seem to affect the formation of spores directly; the latter are formed with full access of oxygen and fail to be formed in its absence. Many special variations in the behavior of the different species are noted. Lack of nutriment checks growth, and under certain other conditions may appear to lead to spore production, but it is not itself a cause for this. Several other fungi are considered. Among other points, it is noted that Mucor produces zygospores under the same general conditions as those under which it produces sporangia, but that zygospores need more oxygen for their formation.—B. E. LIVINGSTON.

SPINDLE FORMATION at the first division of the pollen mother-cell of *Larix europaea* DC. has been described in great detail by Dr. Allen.[11] Late in October the pollen mother-cells are easily distinguished, but division does not occur until the following spring. Five stages in the formation of the spindle are described, viz., the preradial stages, the radial stages, formation

[8] VINES, S. H. Proteolytic enzymes in plants. II. Annals of Botany **17**: 597–616. 1903.

[9] BUSCALIONI and FERMI, Studio degli enzimi proteolytici e peptonizzanti dei vegetali. Annuario R. Ist. Bot. Roma **7**: 99. 1898.

[10] HANSEN, E. C., Recherches sur la physiologie et la morphologie des ferments alcoholiques. Compt. Rend. Labor. Carlsberg **5**: 69–107. *figs. 4.* 1902.

[11] ALLEN, C. E., The early stages of spindle formation in the pollen mother-cells of Larix. Ann. Botany **17**: 281–312. *pls. 14–15.* 1903.

of the felt, the multipolar spindle, and the completion of the spindle. The conclusion is reached that, from the very early prophases, there is present in the cytoplasm a distinct fibrous system which, in conjunction with another set of fibers of nuclear origin, forms the spindle. The fibers of an early reticulum become arranged into a radial system; this in large part passes into an extra-nuclear felt, and the fibers of the felt form the extra-nuclear portions of the spindle. The fibers are something more than lines of force or expressions of strains or stresses. They are organs with distinct chemical and physical properties which determine their power to do particular kinds of work. No centrosomes were observed at any stage in mitosis.—CHARLES J. CHAMBERLAIN.

H. O. JUEL[12] has recently studied the development of the megaspore in Casuarina, basing his results upon material of an undetermined species collected in Algeria in January 1901, and material of *C. quadrivalvis* collected at Naples in March of the same year. The principal results are as follows: Each of the numerous embryo sac mother-cells, by two successive divisions, gives rise to four megaspores. The cells of the archesporium are distinguished by their larger nuclei and denser contents. The first nuclear division in the megaspore mother-cell is marked by the usual synapsis stage and by a reduction in the number of chromosomes. The number of chromosomes at this divison was not determined definitely, but was not less than eight nor more than twelve, while the number in sporophytic cells was about twice as large. Bodies of kinoplasmic aspect appear at or beyond the poles of the spindle during the mitoses which give rise to the four megaspores, but these bodies are not regarded as centrospheres. They resemble the dense areas which have been described in various gymnosperms. The later stages were not studied, but the writer remarks that in regard to the development of the embryo sac, the entrance of the pollen tube and the formation of the embryo, he can only confirm the account of Treub.—CHARLES J. CHAMBERLAIN.

THE REINVESTIGATION of the fossil, *Williamsonia gigas* Carr.,[13] was suggested by Wieland's researches upon Cycadoidea, and there seems to be considerable resemblance between the two forms.

According to the present account, the structures in *Williamsonia gigas* which have been described as "male flowers" are really the axes of ovulate strobili from which the layer of ovules has become detached after maturity. The staminate structures were probably comparable to those described by

[12] JUEL, H. O., Ein Beitrag zur Entwickelungsgeschichte der Samenanlage von Casuarina. Flora **92**: 284–293. *pl. 8.* 1903.

[13] LIGNIER, O., Le fruit du *Williamsonia gigas* Carr. et les Bennettitales, documents nouveaux et notes critique. Mémoires de la Société Linnéenne de Normandie **21**: 19–56. *figs. 9.* 1903.

Wieland for *Cycadoidea ingens*. The fruit of the Bennettitales should be considered, not as a flower, but as an inflorescence.

A diagram showing the relationships of great groups is submitted. From the Protopteridea, the ancestors of the Filicales, is derived a stock which becomes differentiated into two main lines, the Salisburiales and Cordaitales.

At an early period the Cycadales were derived from the Salisburiales and, later, the Coniferales came from the same stock. From the Cordaitales at an early period came the Bennettitales and, later, the Gnetales and Angiosperms. More must be known of the life history of fossil forms lying between pteridophytes and gymnosperms, and also of fossils in these two groups, before a satisfactory diagram of relationships can be constructed.—CHARLES J. CHAMBERLAIN.

ACCORDING TO THE INVESTIGATIONS of J. Brzezinski,[14] the canker disease of trees, long attributed to *Nectria ditissima*, is never caused by this fungus, which, in the opinion of the author, is merely a saprophyte on dead portions of the bark. Inoculations from pure cultures of Nectria failed to produce the disease. The author regards certain bacteria which he found growing in the wood as the true cause of the injury. Three species are described, viz., *Bacterium mali*, *B. pyri*, and *B. coryli*, growing respectively on apple, pear, and hazel. They differ but slightly in cultural characteristics. Inoculations of *B. mali* and *B. pyri* in the wood of apple and pear, respectively, produced discolored areas which gradually extended for a period of several years, forming darkened lines in the wood. In three instances only were small cankers produced on apple trees. The author regards the canker wound merely as one of the external manifestations of the bacteriosis from which the tree is suffering. The disease may manifest itself also as general bacteriosis causing a sickly appearance of the whole tree and producing chlorosis in pear trees. Further, irregular knots on the limbs, a form of twig blight, and root knots are regarded as manifestations of the disease. The twig blight seems to resemble the disease produced on young apple twigs by *Bacillus amylovorus* Burrill. The root knots referred to are "crown galls."—H. HASSELBRING.

PAUL discusses the functions of the rhizoids of mosses and announces certain conclusions,[15] which the writer has held and taught for a number of years, as a result of his observation of the structure and development of these organs. Paul brings no experimental evidence, but relies on more extensive data of the same kind. He holds that the chief function of rhizoids is anchorage; as accessory functions he recognizes (1) the capillary storage and conduction of water by felted rhizoids, and (2) the absorption of water and

[14] BRZEZINSKI, J., Le chancre des arbres, ses causes et ses symptomes. Bull. Acad. Sci. de Cracovie **1903**: 95–143. *pls. 2–8*.

[15] PAUL, H., Beiträge zur Biologie der Laubmoosrhizoiden. Bot. Jahrb. System. **32**: 231–274. 1903.

solutes as by any other part of the body. The support for this view is found in the fact that where anchoring organs are most needed there they are developed, and with evident adaptations in form and length of filament to surface and texture of substratum. In epiphytic and rock species they are best developed; in streaming mosses they form a dense tuft with strongly thickened walls, probably variable according to speed of current; but free floating species have no rhizoids. Paul questions the existence of saprophytic mosses, holding that of such species most grow well also on other sub-strata; that the solution of vegetable membranes by rhizoids is improbable; that penetration is made possible by the pioneer activity of other organisms; and that the nutritive activity of the protonema and leaves is adequate. He finds no evidence that the rhizoids of rock species in any way attack or destroy the rocks by secretions. What disintegration they produce is by holding water. He expressly disclaims denying absorption of water and solutes by rhizoids, but holds that this is only such (or even not so much) as other parts of the body do. No secretions by rhizoids dissolve the substratum. Rhizoids are therefore by no means equivalent physiologically to root hairs. —C. R. B.

NEWS.

DR. G. M. HOLFERTY has been appointed instructor in botany in the high school of St. Louis, Mo.

DR. J. F. GARBER has been appointed professor of biology in the state normal school at River Falls, Wis.

MR. H. H. YORK, assistant in botany at De Pauw University, has been appointed fellow in botany in the Ohio State University for 1903.

PROFESSOR J. H. SCHAFFNER, of the Ohio State University, spent the summer vacation continuing his special studies on the flora of Kansas.

DR. T. C. FRYE, professor of biology *ad interim* in Morningside College, Sioux City, Iowa, has been appointed professor of botany in the University of Washington.

MR. EDMUND P. SHELDON has been appointed superintendent of the Oregon State Forestry exhibit for the Louisiana Purchase Exhibition at St. Louis in 1904.

DR. H. C. COWLES is conducting a party from the University of Chicago, which is engaged in ecological work in Arizona. The party will examine the aspects of both desert and mountain floras.

DR. AUGUSTIN GATTINGER, author of a flora of Tennessee and for many years the most active collector in the state, died in Nashville July 18, at the age of seventy-eight. He was a native of Munich.

PROFESSOR HENRY G. JESUP, for twenty-two years professor of botany in Dartmouth College, died June 15 at the age of seventy-seven. He retired from the active duties of his post four years ago and was made professor emeritus.

AT THE University of Minnesota A. M. Johnson has been appointed scholar in botany. Miss Catherine Hillesheim has been appointed assistant on the Geological and Natural History Survey, *vice* Otto Rosendahl who has entered the University of Berlin.

IN THE University of Missouri E. H. Favor, assistant in botany, has been transferred to the department of horticulture; Howard S. Reed, of the University of Michigan, and Charles Brooks, of the University of Indiana, have been appointed assistants in botany.

THE NEW TROPICAL LABORATORY at Paramaribo, of which an account was given by Professor F. A. F. C. Went in the June number of this journal, will be under the direction of Dr. C. J. J. van Hall, who has been appointed

inspector of agriculture for the Dutch West Indies. Dr. van Hall has been botanist at the Phytopathological Laboratory Willie Commelin Scholten at Amsterdam.

PROFESSOR W. A. KELLERMAN and Assistant O. E. Jennings conducted the botanical work of the Ohio State University Lake Laboratory at Sandusky, Ohio, in July and August. Twenty-five students were enrolled. During the latter part of August and early September Professor Kellerman made extensive collections of fungi, especially the parasitic species, on the Cheat Mountains, Randolph county, West Virginia.

THE ORGANIZATION of the Society for Horticultural Science recently proposed has been decided upon. The proposition met with a wide, enthusiastic, and almost unanimously favorable reception, not only by horticulturists, but also by a considerable number of botanists and other scientists. The need of the society is keenly felt and the time appears ripe for inaugurating the new movement. An attendance of at least thirty of those interested is assured for the first meeting, which is to be held in connection with the annual meeting of the American Pomological Society at Boston. Professor L. H. Bailey will preside. A preliminary meeting for organization and conference will be held in the rooms of the Massachusetts Horticultural Society September 9.

MR. CYRUS G. PRINGLE, who last year accepted the position of keeper of the herbarium of the University of Vermont, started from that institution the first of August upon his nineteenth consecutive annual collecting journey to Mexico. Since his return last February he has installed his herbarium at the university and distributed to other herbaria over 30,000 sheets of plants, including his Mexican collections of 1901 and 1902, and that made last January in Cuba. The Mexican collection of 1902 was an especially rich one. Of the 280 species collected for the first time fully one-fourth were new. He will this year continue his explorations of the southern Andean system of Mexico, taking with him one or two assistants. Dr. J. N. Rose, of the National Museum, plans to join him with another assistant in September.

ON ACCOUNT of an unexpected veto by the governor of the appropriation for the New York State College of Forestry, the trustees of Cornell University, at which the college was located, have announced the suspension of this work. The action of the governor is one that cannot be justified from any point of view. A flourishing college had been organized at which several hundred students were in attendance, forestry work upon the reserve in the Adirondacks had been well begun, contracts had been entered into with important wood manufacturing companies for a supply during a term of years, and the whole country was looking to this college with great interest as a well-managed scientific undertaking. We hope that the friends of the college will make known the influences which have brought about this curious action of the governor. It would appear that the trustees of Cornell Uni-

versity might have minimized in some way the injurious veto. Their action in immediately abandoning the Forestry College seems scarcely justified by their public letter.

THE EXPLORATION operations of the New York Botanical Garden in the West Indies have been prosecuted with greater vigor in 1903 than during any previous season. Dr. N. L. Britton and Mrs. Britton made one expedition to the province of Santa Clara in Cuba, accompanied by Mr. J. Shafer, custodian in botany of the Carnegie Museum, Pittsburg, and a second accompanied by Mr. Percy Wilson, of the Garden; Professor F. S. Earle has visited Cuba, Porto Rico, and Jamaica; Dr. M. A. Howe made an extensive collection of marine algae along the coast of Porto Rico; and Mr. George V. Nash, accompanied by Mr. Harry Baker, made collections along the northern side of Hayti. Dr. D. T. MacDougal spent July in Jamaica investigating the facilities afforded for botanical investigations of all kinds by the laboratories and plantations at Cinchona. Professor L. M. Underwood, of Columbia University, also made extensive collections in Cuba and Jamaica by the aid of funds from the Garden and the Hermann Research Fund of the Scientific Alliance: and Professor F. E. Lloyd, of Teachers College, Columbia University, operated on a similar basis in Dominica. All of these expeditions were so carried out that the results accruing to the Garden consisted of living plants, museum and laboratory material, and herbarium specimens. Other collectors visiting this region also furnished material to the Garden. Mr. Percy Wilson made an extensive visit to Honduras to obtain herbarium and museum material, while Mr. L. R. Abrams, of Stanford University, is making an investigation of the flora of southern California by the aid of the Garden. Mr. R. M. Harper, a student of the Garden, has spent the summer in field work in Georgia.

On September 1 Mr. R. S. Williams, who has been appointed collector for the Garden for the Philippines, started for Manila for the purpose of beginning explorations planned to extend over a series of years.

Miss A. M. Vail, the librarian of the Garden, attended the auction sale of the Jordan botanical library in Paris in May, from which over seven hundred volumes were secured for the library.

Dr. Arthur Hollick carried out some investigations of the Cretaceous flora of Long Island for the U. S. Geological Survey early in the year, and spent the summer on detached duty for the same bureau, making an investigation of the fossil flora of the Yukon district. Professor F. S. Earle made a survey of Porto Rico in March for the U. S. Experiment Station Bureau, and Dr. D. T. MacDougal, as a member of the Advisory Board of the Carnegie Desert Laboratory participated in the surveying tour of Mexico and the southwest during February, which resulted in the location of that institution at Tucson, Ariz.

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AN ECOLOGIC STUDY OF THE FLORA OF MOUNTAINOUS NORTH CAROLINA.

JOHN W. HARSHBERGER.

TOPOGRAPHY.

THE mountain region of North Carolina is not a unit, dominated by a single range or group of mountains, but is a complex containing several features of nearly equal topographic importance. These are (1) the Blue Ridge, (2) the eastern Monadnocks and Piedmont valleys, (3) the Unaka Range, (4) the central mountain groups and intermontane valleys.[1]

The Blue Ridge.—The Blue Ridge may be regarded as forming the extreme eastern range of the Appalachian Mountains, carrying the main divide between the Atlantic and Gulf drainage. It reaches its greatest height in Grandfather Mountain, with an altitude of 5,964^{ft} (1,817^{m}). Three other peaks reach above 5,000^{ft} (1,525^{m}), and a dozen or more, most of them in North Carolina, are above 4,000^{ft} (1,220^{m}). The most striking topographic feature of the Blue Ridge is the great difference in slopes on its opposite sides, for it is steep on the eastern and gradual on the western slopes. The eastward-flowing streams have cut back into the mountain belt, and, having the advantage of a more direct course to the sea, have encroached upon the territory of the westward-flowing streams, and have robbed them of portions of their drainage basins.

The eastern Monadnocks and Piedmont Valleys.—The eastern Monadnocks form several groups of mountains along the extreme

[1] HAYES, C. WILLIS, The Southern Appalachians. National Geographic Magazine 1: 319.

eastern border of the mountain belt, which have been more or less completely isolated by the erosion of eastward-flowing streams. The most important are the Brushy, South, and Saluda Mountains.

The Unaka Range.— The Unaka Range may be divided into a northern and a southern division. The northern division unites in the region of Grandfather Mountain with the Blue Ridge. From this point due west sixty miles (96^{km}), an irregular mountain mass extends to Paint Rock on the French Broad River. Compared with the Blue Ridge, the Unaka Range reaches a considerably greater average altitude, and contains most of the higher peaks in the southern Appalachians. Not only are these mountains higher, but their slopes are steeper, and their outlines more angular and rugged. The Unakas are equally steep on both sides, and slopes with a descent from crest to stream of 4,000^{ft} (1,220^{m}) are not uncommon. Many spurs leave the central chain, and between them are deep V-shaped ravines.

Central mountain groups and valleys.— From a commanding position somewhere on the Unaka Range, there may be seen stretching to the east and south a confused aggregation of peaks, ridges, and domes. The cultivated valleys are generally hidden from view, and, except for an occasional clearing and the grassy "balds" on a few of the higher domes, the whole region appears to be covered with a forest mantle. The interior mountains rise to considerable elevations. A very large number of summits reach altitudes between 4,000 and 5,000^{ft} (1,220–1,525^{m}), and a few culminate above 6,000^{ft} (1,825^{m}). The Black Mountains contain the highest peaks of the Appalachian Mountains, and from Roan Mountain they appear as a huge elongated range, broken into elevated domes, while the range culminates in Mount Mitchell, 6,711^{ft} (2,045^{m}), the highest point east of the Mississippi and 425^{ft} (130^{m}) higher than Mount Washington. Between these groups, and forming a sort of platform above which they arise, are many broad valleys, commonest toward the head of the streams. Only the smaller streams are flowing at the level of these valleys. Down-stream toward the northwest the broad valleys are found to be more and more deeply cut, until

these occupy deep narrow gorges. The broad valleys must have been formed at base level, before the commencement of the gorge cutting, and they afford the best possible evidence that the altitude of the region in which they are found has been increased by elevation in comparatively recent times.

HYDROGRAPHY.

The waters falling upon the several parts of this future National Park find their way eastward to the Atlantic, or southward directly to the Gulf of Mexico, or to the Mississippi River and thence to the Gulf. The divide between the Atlantic and Gulf drainage follows the crest of the Blue Ridge. The eastward-flowing streams are pressing this divide gradually westward by the capture of territory from less favorably situated streams west of the divide. Northwest of the divide the streams flow at first in the high broad valleys, then in deepening channels, directly to the higher, more rugged Unakas, which they cut through in narrow gorges, emerging upon the Appalachian Valley, those south of New River draining their waters into the Tennessee River.[2]

PHYSIOGRAPHY AND GEOLOGY.

The history of this region, as far as it concerns this paper, begins with the Cretaceous period. At least two great cycles of erosion are recorded in the southern Appalachians, in which the surface of an old continent was worn down from a considerable altitude nearly to base level. Shortly after the close of the Carboniferous period, the entire southern Appalachian province was finally lifted above sea level, and its subsequent history is recorded in the land forms. Following this uplift was a long period, during which the region was subjected to the physiographic processes constituting gradation. Finally, toward the close of the Cretaceous period, the whole province was reduced to a nearly featureless plain, the Cumberland peneplain, relieved

[2] See Hydrography of the southern Appalachian Mountain region. Water Supply and Irrigation Papers. U. S. Geological Survey, nos. 62 and 63. 8vo, 190 pages. Washington. 1902. These two papers by Henry A. Pressey give systematic measurements of the streams in the southern Appalachian Mountain district, and other data of special interest to the ecologist.

only by a few groups of hills where the highest mountains now stand. After the processes of base leveling were nearly completed, that is, toward the close of the Cretaceous period, the region was again uplifted, but unequally, so that at the same time its surface was warped. The streams had become sluggish, but the effect of the uplift was to stimulate them to renewed activity,[3] so that they began cutting upon the last-formed peneplain, a process in which they are still engaged.

PHYSIOGRAPHIC CHANGES INFLUENCING THE DISTRIBUTION OF PLANTS.

Constant change must have taken place in the flora, through the physiographic shifts in the continent, which have been described as taking place in the region of the southern Appalachians. New species were appearing by the process of mutation. Other species were crowded for room by the change of level and the wearing away of strata to which they had adapted themselves, for "if we suppose that the earlier Mesozoic uplands were the seat of the existing dicotyledons, then by the lowering of the surface by gradual consumption of the interstream areas, these forms must have been brought into conflict with the ancient flora of the lowlands and thereby forced into a contest for supremacy."[4] These changes in the physical condition of whole areas produced coincident changes in the constituent plants of the several ecologic regions. Xerophytes were replaced by mesophytes; mesophytes, by the wearing away of the soil and the formation of cliffs by xerophytes. Hydrophytes replaced mesophytes when an area became too wet for the tenancy of ordinary plants. Mesophytes replaced hydrophytes, as a lake area was robbed of its water by some newly encroaching stream. All of these changes were represented in the mountain region of North Carolina, and the plants involved in the readjustment to altered conditions were Cretaceous or Tertiary plants. With the development of the Cumberland peneplain, the forest covering, if one existed at that time (and we have no reason for

[3] HAYES, The southern Appalachians, *loc. cit.* 330.

[4] WOODWORTH, J. B., The relation between base leveling and organic evolution. The American Geologist **14**: 231.

believing that a heavy forest did not exist at that early date), was a mesophytic one with the addition of representative herbaceous plants that have not been preserved.

With the uplift of this plain, followed by its planing down by streams, valleys and gorges were created, and rocky strata were exposed, which supported, as such physiographic formations support today, a xerophytic flora. The character of the rocky outcrop influences the particular kind of vegetation, so that we may have a different flora with the same exposure of light, heat, and moisture, if the rocky formations are different. This does not depend so much upon the chemical composition of two different strata, as shown by Cowles,[5] but it is because one formation is further along in its life-history than is the other, so that the vegetation of the clay hill today may be seen on a sand hill in the future. With the widening out of the valley by erosion, and the slackening of the flow of any stream by the reduction of the elevations to base level, the xerophytes of the hillsides will be replaced by the mesophytes of the peneplain. The laws that control changes in the plant covering of a country are, therefore, plainly physiographic and edaphic, if the meteorologic conditions remain the same. We may have broad flood plains, hills, cañons, lakes, and swamps, depending upon the history of the ever-changing topography. Wherever hills are being eroded, rivers widened, waterfalls eliminated, lakes filled, or coastal plains enlarged, there is found a constant change in the plant societies, or a succession in definite order of plant groups. In any land which has undergone degradation from a mountainous topography to a peneplain, we ought to find a marked change in the organisms at the close of the cycle of denudation. In the first stages of change from original constructional topography, effects will be discernible. Sculptured slopes with ravines, sharp divides, and peaks cradle species and varieties by barriers which oppose ingress and egress.

In the progress toward final base leveling, the repeated diversion of the streams, or the reversals of drainage, are a constant

[5] Cowles, H. C., The influence of underlying rocks on the character of the vegetation. Bulletin American Bureau of Geography **2**:— [pp. 26]. Je and D 1901.

cause of changed conditions which Alfred Russell Wallace emphasizes as of importance in the modification of species.[6] The cycle begins in a mountainous tract with least facility for migration of species, and ends in broad lowlands, which favor the easy migration and wide distribution of plants and animals.[7]

The distribution of plants in the region of the southern Appalachians demonstrates the above-mentioned facts. Kearney[8] has called attention to the presence of a Lower Austral (austro-riparian) element in the flora of the mountains of North Carolina. Over one hundred species, which are most abundant and most widely distributed in the austro-riparian area, are known to occur in the mountains at an elevation of 1,000^{ft} (300^{m}) or more. Below that altitude the flora of the southern Appalachian region is mainly Carolinian, and the presence in its midst of numerous austro-riparian forms would be expected. The occurrence, however, of Lower Austral species at higher elevations in the midst of a chiefly transition flora is the noteworthy fact in the distribution of plants in the southern Appalachians. In studying this flora, one soon reaches the conclusion that it comprises two categories of species, which are markedly different, not only in their systematic relationships, present distribution, and past history, but even to a considerable degree in their ecologic constitution. Two types of plants may be distinguished: those of neotropic origin, which have in all likelihood made their first appearance in the Appalachian region in geologically very modern times, probably after the close of the glacial epoch; and those not of neotropic origin, which probably represent the more or less modified descendants of the flora that in later Eocene or Miocene time extended to high northern latitudes, represented in eastern North America by two closely allied species, one in the coastal plain, and the other in the Appalachian region.

In order to explain the facts in the case, botanists have had

[6] WALLACE, A. R., Darwinism, chap. v.

[7] WOODWORTH, J. D., The relation between base leveling and organic evolution. The American Geologist **14**: 217. 1894.

[8] KEARNEY, The lower austral element in the flora of the southern Appalachian region. Science N. S. **12**: 831.

recourse to the movement of glaciers southward during the ice age. It appears to the writer that the alternation of cold and warm periods is not necessary to account for the facts described above. An attempt is made in what follows to outline an alternative hypothesis which appears to be a more satisfactory exposition of the case. The elevation of the southern Appalachian region from the Cumberland base level satisfactorily accounts for the differentiation of the corresponding mountain and coastal species. The species now found on the mountains adapted themselves to the higher elevations, and, being more plastic, were wrought upon by the forces which were and are at work in the gradation of the southern Appalachian region. For no fact in biology is better known than the capacity of some species to endure a wide range of physical conditions, while others are fatally sensitive to comparatively slight differences of environment. The modification of the species above mentioned was influenced by the rapid change in the physiography and topography of the country, and not by the glacial ice-sheet, which during a late geologic epoch covered the whole of North America. The oscillations of level are known to have taken place, and it is conceivable that the progenitors of the austroriparian plants of the mountains and coastal plain, specifically identical, mingled when the country was a level peneplain, becoming differentiated as the elevation of the land became more marked. The distribution of plants which represent the characteristic flora of Eocene and Miocene times is thus accounted for.

We have then, in the physiographic changes which have taken place in this mountain region, an explanation of the peculiarities of the flora of the southern Appalachians, which displays certain anomalies of distribution and isolation of monotypic plants. The presence of *Hudsonia montana* Nutt. on the summit of Table Rock is thus explained.[9] Table Rock is an undenuded remnant of a former peneplain, and it is likely that *Hudsonia montana* Nutt. was once more extended in its distribution, but has been isolated by the erosion of the larger part of the plain on which it formerly grew in abundance. *Dicentra*

[9] Collected there by Dr. John K. Small.

eximia DC. is another illustration, growing in a rather restricted area in the Doe River Gorge, where the river cuts between Iron Mountain and Gap Creek Mountain, North Carolina. *Shortia galacifolia* Torr. & Gray, *Lilium Grayi* S. Wats. on Roan Mountain, *Buckleya distichophylla* Torr. on Paint Rock are examples of this same local distribution and isolation.

PHENOLOGIC DISTRIBUTION OF PLANTS.

Four kinds of plants with reference to their phenologic distribution may be distinguished in the vegetation of the forests of eastern North America; viz.: plants of boreal genera (Arctic, Hudsonian, Canadian species), plants of temperate genera (Alleghanian and Carolinian), plants of warmer temperate climate (austro-riparian), and neotropic genera.

Both boreal and temperate species bloom in the spring before they are shaded by the leafing trees, but for different reasons. The plants of temperate origin vegetate and blossom in the spring before the trees are in leaf, because, as a matter of light relationship, it is the only season in which the functions of these plants can be performed adequately, and this presupposes the influence of a certain number of heat units greater than for boreal species and less than for those of more southern origin. A more detailed statement on this subject will be made subsequently. The boreal plants, however, of the eastern Appalachian forests, blossom and vegetate early in the season, because that is the part of the year at which the development of these species, which require a minimum of heat units, is most adequately performed.[10] The writer has shown this in a detailed manner in a paper published in *Science*.[11] The Scandinavian element of our flora consists of plants which mature their seeds quickly before the summer is well advanced. This marks them

[10] The presence of many boreal plants in the forests and peat bogs of the northern states is accounted for by the encroachment of tree vegetation, after the glacial epoch, upon the areas occupied by the boreal plants, which surrounded by the trees, were destroyed or compelled to grow during the period when the trees are leafless. The movement of trees northward was occasioned by the fact that the land area, left bare by the retreat of the glaciers, was one of low tension, while the country to the south, as we have seen, was one of high tension.

[11] HARSHBERGER, The origin of our vernal flora. Science N. S. 1:92–98. Ja 25. 1895.

as physiologically adapted to the influences of a previous short glacial summer. This rapid growth is insured by the activities of the plant during the previous short season in storing up large amounts of reserve material for the next brief season's growth. Even under favorable conditions of summer heat, every external perceptible vital motion in these boreal plants ceases, and it is only after a dormant period of some months, that growth can commence anew. This periodic alternation of vegetative activity and rest is in general so regulated that for a given species of plant both occur at definite times of the year, leading to the inference that the periodicity only depends upon the alternation of the seasons, and, therefore, chiefly upon that of temperature and moisture. The plants of Scandinavian affinity agree physiologically in having a periodic growth and rest. The following diagrams will illustrate this. Diagram *B*, if compared with diagram *A*, shows that the period of vegetative activity of our spring plants of boreal origin corresponds with an arctic or glacial summer, while the dormant period corresponds with an arctic winter, although our present summer has encroached on the former glacial winter.

A. Astronomical Year during Glacial Period.

Vegetative Period	Flowering and Reproductive Period	Dormant Period
Growing Period of Plants		
Arctic Summer		Arctic Winter

B. Astronomical Year — 1903.

Vegetation	Flowers	Dormant Period	
Growing Period of Boreal Plants		Dormancy of Summer ← →	Dormancy of Winter
Present Summer			Present Winter

The plants of warmer temperate climate (austro-riparian species) require a greater number of heat units than those plants just described, and their distribution at present depends largely upon temperature and soil conditions. In the case of the austro-riparian species found in the southern Appalachian mountains, two factors are probably most effective in permitting these species to maintain themselves in what would seem to be an unfriendly environment, viz., amount of insolation and the nature of the soil.[12]

A favorite situation in the mountains for colonies of lower austral species is on the southern exposure of hills, where the angle of inclination and the position with reference to the sun insure the greatest possible amount of insolation. The soil preferred by the great majority of these species is light, sandy, and poor in organic material; it is consequently readily permeable to water and becomes quickly and strongly heated, being thus similar to the soils which cover a great part of the coastal plain.

Unfortunately no phenologic data are at hand with reference to the plants of warmer temperate character. In lieu of exact data, a reference to Chapman's *Flora*[13] may assist in determining the position of these plants with reference to the period of flowering. Those plants not of neotropic origin, which are probably the more or less modified descendants of that characteristic flora which existed in Eocene and Miocene times, and species of genera that appear to be on the wane, blossom in general, according to Chapman, from May to July, and are not looked upon as spring plants, which blossom from March until May. The neotropic element in the flora of the eastern United States is represented by plants that bloom in general from June until October,[14] and are therefore summer and autumn species. This result of a phenologic tabulation of the austro-riparian plants might have been expected, when the origin and physio-

[12] KEARNEY, *loc. cit.* 841.

[13] CHAPMAN, Flora of the southern United States. 3d ed.

[14] Another group of plants, derived like the Cactaceae and Compositae from the southwest, bloom at about the same period as the plants of neotropic origin. See my paper in Science, *loc. cit.*

logic constitution of these plants is taken into consideration; for, according to the laws of temperature control of plants, species of neotropic and warm temperate origin need a large sum of heat units to carry on adequately their life-processes, and these are not properly carried on unless the specific number of heat units is provided in the environment.

INFLUENCE OF GLACIERS ON THE FLORA OF NORTH CAROLINA.

Upon the retreat of the ice-sheet, that portion of the continent north of the terminal moraine was tenanted again by plants that migrated northward, which as species were adapted to a cold temperate climate. A large number of these species came from the southern Appalachians and adjoining regions, where they had remained undisturbed in their original haunts during the long ice age, and were in a plastic condition for growth in a new environment, through the influence of the pressure of species upon each other in their southern home, and through the physiographic vicissitudes to which these fictile forms were subjected. Many species, therefore, growing in the North Carolina mountains, found congenial conditions in the more extensive land areas in the north.

An inspection of the forest maps to be found in the ninth volume of the Tenth Census Report, *Forest Trees of North America*, will show that there is a center of distribution which comprehends the area of the present states of southern and central Pennsylvania, West Virginia, Kentucky, Tennessee, western North Carolina, southwestern Virginia, northern Georgia, Alabama, Mississippi, where the largest number of species of the most important genera of North American deciduous trees will be found. A study of these maps reveals an important fact, that the spread of the species from this common center has been in a series of more or less concentric waves. Three waves may be distinguished. The first wave consisted of the distinctly glacial flora, which skirted the border of the ice-sheet. The second consisted of the present boreal forms, and the third was a wave of deciduous shrubs and trees, oaks, hickories, and a host of others. The species most successfully provided with means of distribution and most easily adjustable extended furthest

from the original home after the glacial epoch, which circumscribed the area of the original dense forest of the Miocene period. The outer confines of any particular genus is usually occupied, as shown in the maps, by a single species. Nearer the center two species are found; still nearer, if the genus is a large one, three, and still nearer four, etc. The position of the various shades of green on the maps suggests the circles of impulse produced when a stone is thrown into a basin of water. Theoretically these waves spread circumferentially in all directions, unless they meet with obstacles, when they are deflected. Similarly, the maps suggest a series of distributional impulses, by which the various species of oaks, ashes, hickories, and chestnuts were forced out from a parent forest of great density into the area left bare by the retreat of the great ice-sheet. The force which impelled this migration outward from the original forest, a relict of the continental forest of Miocene times, was the tension produced by the species associated together and in a struggle for supremacy, as regards room, light, etc. This struggle for existence must have been intense, as evidenced by the great size, height, and straightness of bole of the deciduous forest trees. Only two alternatives were left the species composing this original forest, namely, extinction or migration. Fortunately for the forest, an area of little or no tension was opened up upon the retreat of the glacial ice. The migration from an area of great tension has been and always will be toward an area of little tension.

MacMillan[15] remarks on this point, with reference to the character of the Minnesota flora, that it has been shown that, while the valley of the Minnesota is geographically central, it is by no means botanically central, but, on the contrary, strongly southern and eastern. Bessey[16] has shown that the trees and shrubs of Nebraska have come up the Missouri bottoms and spread from the southeastern corner of the state west and northwest. Mason states that the trees of Kansas show the same

[15] MACMILLAN, The Metaspermae of the Minnesota Valley 758, 759. 1892.

[16] BESSEY, The forests and forest trees of Nebraska. Ann. Rep. State Bd. of Agric. 1899: 79–102.

origin. Adams[17] has demonstrated this clearly in a study of the faunal distribution of animals and in a cursory way with plants.

The marshaling of these facts exhibits the flora of the southern Appalachians and of the mountains of North Carolina in a new light. That the plants of the northeastern and north central United States (except those left as high northern plants on the nunataks and non-glaciated islands and those of cold temperate habit) are derived from the region of the southern Appalachians, adds considerable zest to the study of the flora of these elevated mountain lands.

PRINCIPLES UNDERLYING THE DISTRIBUTION OF PLANTS IN EASTERN AMERICA.

It is advisable at this point to make a restatement of the principles underlying the distribution of plants in eastern America. These statements are derived from the work done by Gray, Hooker, and others on the distribution of North American plants, with additional facts which seem to the writer necessary to mention because of recent work that has been published with reference to the flora of North America in general.

1. Subsequent to the great Cretaceous uplift in a favorable period of mutation, the north temperate regions of Europe, Asia, and America which extended to high northern latitudes became the habitat of dicotyledons and monocotyledons identical as species in most important points.

This region was occupied by a forest of great density,[18] composed of numerous species of trees, shrubs, and herbaceous plants, and these plants were subsequently definitely allocated during preglacial times to certain geographic areas by the planing down of the country to base level.

3. The movement of the glaciers southward over the north-

[17] ADAMS, CHAS. C., Southeastern United States as a center of geographical distribution of flora and fauna. Biological Bulletin **3**: 115–129. Jl 1902.

[18] GRAY, ASA, Sequoia and its history. Proceedings American Association Advancement of Science **21**: 1. 1872. Scientific papers of ASA GRAY **2**: 142; also *ibid.* **2**: 204. *Cf.* GRAY, Forest geography and archæology. American Journal of Science **16**: 85–94; 183–194.

land exterminated the plants of preglacial times without forcing a migration southward, except the northern herbs and trees left on the moraines, unglaciated islands, glacier margins, and nunataks of the great ice field.[19]

4. During the late Pleistocene, and also during the interglacial period, the Scandinavian element of the boreal and north temperate floras was introduced by the migration of plants from Scandinavia by the high northern roadway through northern Europe and Asia to North America, and, as shown, these plants remained on the retreat of the glaciers in the far north, and on the alpine summits of the more elevated mountains, or were held trapped in the cool shade of the north temperate forest or isolated in cold sphagnum bogs.

5. The plants of this north temperate region south of the terminal moraine during glacial times remained, on the retreat of the glaciers, in undisturbed possession of their original habitats. During the ice age they were still further reduced in numbers and influenced in their distribution by the physiographic forces constantly at work in the shaping of the continent.

6. Upon the retreat of the ice-sheet the glaciated area was supplied with plants from two main sources: (*a*) the plants that had maintained themselves in the north during the ice age, and (*b*) the contingent of plants supplied by the territory to the south and east.

7. Conclusively, therefore, the facts indicate the absence of a southern migration of plants.[20] Rather, they point to the glaciers as the important factor in the isolation of such botanic regions as eastern North America and eastern Asia, which perforce show affinities in their floral make-up that can be explained only by reference to the principles aforementioned.

[19] WRIGHT and UPHAM, Greenland icefields and life in the north Atlantic 197–198. 1896.

RUSSELL, Glaciers of North America 86 and 117. 1897; also in Annual Report U. S. Geological Survey **13**: 19–21. 1891–92.

WRIGHT, G. FREDERICK, The ice age in North America 57–62. 1891; also American Geologist **8**: 330.

[20] This southern migration seems to the writer well-nigh impossible, because it would mean a movement from an area of lower tension to one of higher tension.

8. Following the glacial period the modification of the plants left in the several widely removed continental areas, eastern North America and eastern Asia, became accentuated, as time elapsed, until the similarities which are marked in the plants of preglacial times became less well defined and the differences evident in the two floras become the feature of recent times.

9. These facts argue for a great antiquity of the flora of the mountains of western North Caroliua. The presence of so many peculiar types of plants, not found elsewhere in America and having their closest relatives in eastern Asia, makes it more certain that groups, now broken up and detached, were once continuous, and that fragmentary groups and isolated forms are but the relics of widespread types, which have been preserved in a few localities where the physical conditions were especially favorable, or where organic competition was less severe.

This important principle is evidenced on every hand as a botanist travels through western North Carolina. The large size of the trees, the close commingling in a dense forest of a great variety of species, the graded-down appearance of the land surface, and the rounded contour of the mountains, all impress the fact upon him that the country through which he travels has been subjected through long ages to the continued action of climatic forces which have carved the land into its present form and influenced the character of the vegetal covering. This impression is greatly heightened, if the following nine criteria for determining the centers of dispersal are applied to the study of the region in question:[21]

1. Location of greatest differentiation of type.
2. Location of dominance or great abundance of individuals.
3. Location of synthetic or closely related forms.
4. Location of maximum size of individuals.
5. Location of greatest productiveness and its relative stability.
6. Continuity and convergence of lines of dispersal.
7. Location of least dependence upon a restricted habitat.
8. Continuity and directness of individual variations, or modi-

[21] ADAMS, CHAS. C., Southeastern United States as a center of geographical distribution of fauna and flora. Biological Bulletin 3: 122.

versity might have minimized in some way the injurious veto. Their action in immediately abandoning the Forestry College seems scarcely justified by their public letter.

THE EXPLORATION operations of the New York Botanical Garden in the West Indies have been prosecuted with greater vigor in 1903 than during any previous season. Dr. N. L. Britton and Mrs. Britton made one expedition to the province of Santa Clara in Cuba, accompanied by Mr. J. Shafer, custodian in botany of the Carnegie Museum, Pittsburg, and a second accompanied by Mr. Percy Wilson, of the Garden; Professor F. S. Earle has visited Cuba, Porto Rico, and Jamaica; Dr. M. A. Howe made an extensive collection of marine algae along the coast of Porto Rico; and Mr. George V. Nash, accompanied by Mr. Harry Baker, made collections along the northern side of Hayti. Dr. D. T. MacDougal spent July in Jamaica investigating the facilities afforded for botanical investigations of all kinds by the laboratories and plantations at Cinchona. Professor L. M. Underwood, of Columbia University, also made extensive collections in Cuba and Jamaica by the aid of funds from the Garden and the Hermann Research Fund of the Scientific Alliance: and Professor F. E. Lloyd, of Teachers College, Columbia University, operated on a similar basis in Dominica. All of these expeditions were so carried out that the results accruing to the Garden consisted of living plants, museum and laboratory material, and herbarium specimens. Other collectors visiting this region also furnished material to the Garden. Mr. Percy Wilson made an extensive visit to Honduras to obtain herbarium and museum material, while Mr. L. R. Abrams, of Stanford University, is making an investigation of the flora of southern California by the aid of the Garden. Mr. R. M. Harper, a student of the Garden, has spent the summer in field work in Georgia.

On September 1 Mr. R. S. Williams, who has been appointed collector for the Garden for the Philippines, started for Manila for the purpose of beginning explorations planned to extend over a series of years.

Miss A. M. Vail, the librarian of the Garden, attended the auction sale of the Jordan botanical library in Paris in May, from which over seven hundred volumes were secured for the library.

Dr. Arthur Hollick carried out some investigations of the Cretaceous flora of Long Island for the U. S. Geological Survey early in the year, and spent the summer on detached duty for the same bureau, making an investigation of the fossil flora of the Yukon district. Professor F. S. Earle made a survey of Porto Rico in March for the U. S. Experiment Station Bureau, and Dr. D. T. MacDougal, as a member of the Advisory Board of the Carnegie Desert Laboratory participated in the surveying tour of Mexico and the southwest during February, which resulted in the location of that institution at Tucson, Ariz.